



# 4th Palaeontological Virtual Congress

**Book of Abstracts**

May 8–22<sup>nd</sup>, 2023



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## 4<sup>th</sup> Palaeontological Virtual Congress

### Book of Abstracts

#### Palaeontology in the virtual era

From an original idea of Vicente D. Crespo

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Following the three previous and successful editions of the Palaeontological Virtual Congress (PVC), organized in December 2018, May 2020, and in 2021 during the COVID19 pandemic, the 4<sup>th</sup> Palaeontological Virtual Congress continues to demonstrate the necessity for virtual meetings in palaeontology.

PVC shows a steady growth compared to previous years, in both participants and contributions. In the 4<sup>th</sup> PVC, more than **723 scientists** from **55 different countries** gathered virtually to watch more than **340 contributions**, an absolute record in terms of participation and number of contributions.

Following the sharp increase in the number of contributions, the 4<sup>th</sup> PVC hosts an even greater diversity of topics. Besides the traditional Sessions of the Paleozoic, Mesozoic, Cenozoic and General Palaeontology, the 4<sup>th</sup> PVC also hosts 8 Keynote presentations, 13 Thematic Sessions, and 3 Virtual Field Trips.

The mission of this Palaeontological Virtual Congress was communitied by 7 Ambassadors and Ambassadors who helped attracting interest and spread our news. Thanks to them, we have been able to enjoy thre greatest national diversity reaching nearly half of the countries on Earth!

We continued to add virtual activities, including a Photography and Palaeoart contest. You can find the wonderful prized photographs and artwork herein.

Also, selected papers coming from this year's communication will feature on a Special Volume of the high-quality peer-reviewed journal *Geobios*, that publishes bimonthly in English original peer-reviewed articles of international interest in any area of palaeontology, palaeobiology, palaeoecology, palaeobiogeography, biostratigraphy, stratigraphy and biogeochemistry.

We would like to thank all our colleagues for organising and coordinating the different workshops. We also want to thank all the authors for submitting their contributions and the numerous reviewers that have made this volume and congress possible. We would also like to give special thanks to all Palaeontological and Geological Societies, Editorials, Museums, and Universities that have supported this initiative.

A handwritten signature in black ink that reads "4th PVC". The letters are stylized and cursive.





A Morning Surprise (*Megaloceros, Homo*)  
Nickolaus Peter  
Palaeoart Competition (Special Mention)

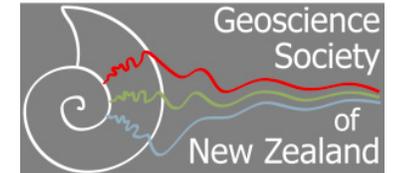




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# Ambassadors/Ambassadresses



## **Elena Cuesta**

Elena Cuesta was born in the Canary Island (Spain). She is a geologist by the Complutense University of Madrid and PhD in Biology by the Autonomous University of Madrid. She has been working during her postdoctoral stage at the Fukui Prefectural University (Japan) and Paleontological Museum of Munich (Germany). Her research is focused in the Paleobiology of theropod dinosaurs, studying their anatomy and evolutionary relationships.

## **Panagiotis D. Sianis**

My name is Panagiotis D. Sianis, but people usually call me Panos. I'm a PhD student from the University of Patras (Greece), specializing in Early Pleistocene large mammal assemblages. I have completed my Bachelor's degree in Geology at the University of Patras and then received a MSc from the same institute. Currently, I reside in Portugal collaborating with Universidade NOVA de Lisboa.

## **Gastón A. Martini**

My name is Gastón A. Martini, alias Tato. I am an Argentinian biologist (from UNRC), doing a Ph.D. in Biological Sciences (at UNC) in my home country. My place of work is located in southern Argentina (CIEMEP-CONICET). I am currently studying a group of glyptodonts from the Santa Cruz Formation (Early Miocene) of Patagonia (Argentina). My research is focused on anatomical, taxonomic, phylogenetic, and paleobiology aspects of them with an emphasis on cranial characters. Last but not least, I am a plant and dog lover and a human of two puppies (Franky and Rufi).

## **Diana Osipova**

My name is Diana Osipova. I obtained my Master's in Kyiv (Ukraine), and had started my research career as a Junior Research Scientist at Institute of Zoology (Ukraine). Starting from that moment I have been interested in and mostly focusing on the study of the evolution of hinge in Bivalvia, and its abnormalities. For the present moment, I continue my project in Academia Sinica (Taiwan), and work with fossil Mollusca specimens, mostly specializing on Pliocene-Pleistocene taxa.

## **Dominique Mediodia**

My name is Dominique P. Mediodia from the Philippines. I am a faculty member of the Institute of Marine Fisheries and Oceanology, College of Fisheries and Ocean Sciences, University of the Philippines Visayas. I am a Ph.D. student at the National Taiwan Normal University. I am a recipient of the Taiwan International Graduate Program (TIGP) offered by Academia Sinica. My study will focus on understanding the relationship between phylogeny, morphology, and biodiversity in fish fossil otoliths using 3D imaging.

## **Sofía Urzagasti-Torres**

My name is Sofía Urzagasti-Torres, I am 25 years old (Bolivian/Argentinian) and I hold a Bachelor's degree in Paleontology from the Universidad Nacional de Río Negro (UNRN) in the city of General Roca, Argentina. Currently, I am pursuing my Ph.D. at the same university and my workplace is the Instituto de Investigación en Paleobiología y Geología (IIPG). I am specializing in Vertebrate and Invertebrate Ichnology and my research topic focuses on Avian Footprints from the Upper Cretaceous of Argentina from an icnotaxonomic, paleobiological, paleoecological and paleoenvironmental perspective.

## **Sara Akboub**

I am Sara AKBOUB, a 25 years old Moroccan Geologist, currently pursuing my PhD in Paleontology and sedimentology at university of Chouaib Doukkali in Morocco. A very passionate, and enthusiast about anything related to fossils, trace fossils and Evolution of environments and species. My current research focuses on the study of vertebrates, invertebrates and insects; living around the end of the Carboniferous and Permian Period. Field work is one of my favorite parts of geology, it's a time traveling journey and that's why I started research in Geology.





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Morning in the forest  
Ferrutxo  
Palaeoart Competition (Special Mention)





**DINOSAUR “MUMMY” AUTOPSY: BIOSTRATINOMIC AND DIAGENETIC EVIDENCE CLARIFIES THE PATHWAY FOR SOFT TISSUE PRESERVATION**

C.A. Boyd



**HOW AND WHEN TO CREATE A RESEARCH PROGRAM IN PALAEOLOGY?  
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**ROMANIAN JURASSIC FLORAS**

M. E. Popa



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Gertrud E. Rössner



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K. Trinajstić *et al.*

# Keynote Presentations





## DINOSAUR “MUMMY” AUTOPSY: BIOSTRATINOMIC AND DIAGENETIC EVIDENCE CLARIFIES THE PATHWAY FOR SOFT TISSUE PRESERVATION

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### Keywords

*Edmontosaurus*, Fossilization, Biostratinomy, Diagenesis, Dinosauria



Clint Boyd is the Senior Paleontologist for the North Dakota Geological Survey and Curator of the North Dakota State Fossil Collection. He manages the State's Fossil Resource Management Program and oversees an expansive Public Fossil Dig program that works with hundreds of people each summer to discover, collect, and preserve North Dakota's prehistoric past. His dissertation work focused on the anatomy and systematic relationships of ornithischian dinosaurs, with a focus on thescelosaurids. He later served as the Haslem Postdoctoral Fellow at the South Dakota School of Mines & Technology studying the diversity of Eocene and Oligocene mammals in the Great Plains Region of North America. In addition to that work, his current research includes the diversity of mosasaurs from North Dakota and exploring the biostratinomy and diagenesis of well-

preserved dinosaurian “mummies” from North America.



Examination of a well-preserved specimen of the hadrosaurid dinosaur *Edmontosaurus* (NDGS 2000) provides insight into the fossilization pathway for dermal tissues (*e.g.*, skin and nails). While the skin is well-preserved in three dimensions, it is deflated and marked by the first documented examples of perimortem carnivore feeding traces on dinosaurian soft tissue. We propose incomplete scavenging of the carcass provided a route for the gases, fluids, and microbes associated with decomposition to escape, allowing more durable dermal tissues to persist through the weeks to months required for desiccation prior to entombment. Analysis of elemental data collected via X-ray fluorescence reveals that the matrix away from the preserved dermal tissues is high in calcium, and moving towards and into the dermal tissues the calcium decreases while iron, manganese, phosphorous, sulfur, and nickel all increase. Additionally, old fractures are present in the rock that extend to the preserved dermal tissues and are surrounded by halos of altered matrix. Those fractures formed after initial cementation of the rock by carbonate (*e.g.*, siderite, calcite) during the development of a paleosol overlying the specimen, allowing surficial waters of differing chemistry to interact with the specimen and adjacent matrix. Petrographic analysis of the matrix in those altered areas reveals replacement of carbonate by more geochemically stable iron oxides (*e.g.*, goethite) and later sulfides (*e.g.*, pyrite). We propose this pattern of multiple phases of mineralization under very specific depositional conditions both enhances dermal tissue fossilization in these specimens and limits their abundance in the fossil record.



## HOW AND WHEN TO CREATE A RESEARCH PROGRAM IN PALAEOLOGY? AN EXAMPLE IN THE STUDY OF THE MIDDLE-UPPER TRIASSIC CONTINENTAL BEDS OF ARGENTINA

J. B. Desojo\*

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### Keywords

Research Program, Archosauriform Research Group, Palaeobiology, Triassic, Argentina



Julia Brenda Desojo mainly works on Archosauriform anatomy, evolution, and Palaeobiology, but is interested in everything to do with Triassic terrestrial ecosystems. She got a MSc. from the Universidad Nacional de La Plata of Buenos Aires in 1997 and a PhD from the Universidad de Buenos Aires of CABA in 2005. As postdoc at the Bayerische Staatssammlung für Paläontologie und Geologie in Munchen, Germany, she initiated an extensive fieldwork project in continental Triassic rocks of La Rioja Province, Argentina, which has yielded abundant new data on Triassic terrestrial ecosystems in South America, also fieldworks in Morocco and South Africa. Since taking on the job as Researcher at CONICET at the Museo Argentino de Ciencias Naturales (MACN) in CABA in 2007, and the Museo de La Plata (MLP) in Buenos Aires in 2016, she has increasingly worked on basal archosaurs anatomy and paleobiology. Since 2015 she furthermore holds a post as teacher assistant at the Facultad de Ciencias Naturales y Museo in La Plata.

Long-term research programs conducted by a professional interdisciplinary team are not very common in vertebrate palaeontology. The Middle-Upper Triassic continental outcrops of Argentina have been studied since the 1960s by local and international researchers with palaeontological and geological approaches. However, interdisciplinary work by palaeontologists, geologists, and other researchers involved in the same research program is less frequent. The Archosauriformes Research Group (ARG) has been working since 2011 to elucidate the ecological roles of archosauriforms, especially pseudosuchian archosaurs, in the Triassic continental communities mainly in South America, with their consequent palaeobiogeographic and biostratigraphic implications in an updated comparative phylogenetic framework. We have been working to increase our knowledge of the Triassic continental faunas, including anatomy and phylogenetic relationships, emphasizing archosauriform palaeobiology (*e.g.*, soft tissue anatomy–paleoneurology and myology, growth dynamics and rates–palaeohistology, ontogeny, modes of life, functional morphology, and trophic habits). This will allow us to understand relevant aspects of the evolutionary history of the archosauriforms in the context of the faunal turnovers that occurred during the Triassic and to analyze the implications that climatic–environmental changes had on the biota during this period. We have been working to collect fossils and their taphonomic and geological data in annual fieldtrips to the Ischigualato-Villa Union Basin in La Rioja Province of northwestern Argentina. These novel specimens and those already housed in institutional collections allow new palaeobiological studies with different approaches (*e.g.*, biomechanics, palaeohistology, palaeoneurology) to have an holistic picture of the ca. 230 million-years-old the continental ecosystems that developed in western Gondwana.





## DINING OUT IN THE MIO-PLIOCENE ON SOUTH AFRICA'S WEST COAST

R. Govender\*

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### Keywords

South Africa, cetacean, seal, early Pliocene, sharks



Romala's palaeontology career began more than twenty years ago through the study of Karoo palaeontology. She obtained her MSc (2002) studying the postcranial anatomy of the Permian dinocephalian, *Tapinocaninus pamela*, the first study of tapinocephalid postcranial anatomy in over 20 years, including a description of the first complete tapinocephalid vertebral column and PhD (2006) studying Triassic dicynodont postcranial anatomy focusing on *Kannemeyeria simocephalus* identifying a second postcranial morphotype (no skull) in South Africa's Cynognathus Assemblage Zone, Trirachodon-Kannemeyeria Subzone (Subzone B). In 2009, as a postdoctoral fellow at the Biological Sciences Department, University of Cape Town, she began her study of Mio-Pliocene fossil marine mammals for the first time in 30 years starting with Langebaanweg. She is uniquely qualified as the only South African palaeontologist studying Cenozoic marine mammals and, to a lesser degree, the occurrence of sharks. Her research has expanded to focus on the Mio-Pliocene fossil marine mammals from the west coast of Southern Africa and applying new techniques to understand the marine mammal fauna populations, taphonomy, palaeoecology and their environment as well as the faunal changes that have occurred in both over the past 5 million years. The success and results of these studies saw her obtain her NRF C rating.



Along the west coast of South Africa marine palaeoenvironments changed from the late Miocene to the early Pliocene. There were embayed areas, lagoonal, estuarine and rivers. The southern African coast was also affected by changes to sea levels that resulted in the formation of islands off the coast. The Benguela Upwelling System was well-established and supported a rich seal and cetacean fauna. The phocid (true) seal, *Homiphoca*, lived off the South African west coast five million years ago with evidence of breeding colonies in the Langebaanweg area during this time. Its home range extended into the Northern Cape as they were probably also capable of switching between feeding regimes that may have been affected by season and food availability. The seals also show signs of pathological changes to their skeletons that affected both the cranial and postcranial skeleton elements. This included osteoarthritis, broken bones, and illness. The presence of young cetaceans suggests that there were potential breeding areas along the coast and the area was frequented by cow-calf pairings as well as other young animals. This may be linked to the presence of estuaries and lagoons along the coast. Damage identified on the seal and cetacean skeletons were also a result of marine and terrestrial carnivore feeding behaviour. Sharks living off the coast 5Ma were feeding on cetaceans and seals; probably scavenged these carcasses. There is also evidence on the bones that terrestrial carnivores were feeding on the seals in the Langebaanweg area. This damage was also most likely caused by scavenging.



## EXCEPTIONALLY BADLY PRESERVED FOSSILS: IT'S OKAY NOT TO BE OKAY!

S. Pereira\*

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### Keywords

Tpnomony, fossilization, Palaeozoic, invertebrates, Portugal



Born in Aveiro (Portugal), degree in Geology (Faculty of Sciences of the University of Lisbon, with last year at Universidad Complutense de Madrid). PhD in Palaeontology and Stratigraphy at the University of Lisbon in 2017 (Trilobites from the Upper Ordovician of the Portuguese Central Iberian Zone). Post-doc researcher (New University of Lisbon; 2018-2019) of the EIT Raw Materials Project "TravelEx". Currently, she is a researcher at the Centro de Geociências of the University of Coimbra and a volunteer professor at the Earth Sciences Department of the University of Coimbra (Portugal). Her fields of research are the systematics, biostratigraphy and palaeoecology of trilobites (lower Palaeozoic of the high-latitude peri-Gondwana realm);

Ordovician paleobiogeography and geodynamics; Ordovician Portuguese Stratigraphy and Geological Mapping. In ancient dark times she was also dedicated to bioerosion of Miocene bivalve shells and the outreach of metallic mineral resources. Generally, she has a good temper (but don't ask her mother).

Humans are naturally attracted to beauty, driven by an inherent natural tendency. Palaeontologists, being human, are therefore drawn to fossils that are complete, stunning, superlative, and extraordinary. The current pressure to be fast and furiously productive, making palaeontologists hostages to an alien index, has led to a bias: extremely badly preserved fossils are not attractive to palaeontologists anymore. This tendency must be avoided at all costs because it hinders research, limiting comprehension. Our knowledge of Earth's history is the result of painstakingly studying all fossils found so far and it would be extremely limited if we only took the so-called lagerstätten and exceptionally preserved specimens into account. Fossilisation is a very demanding process. Fossilising and "surviving" all the processes related to the planet's geodynamics is already exceptional, and if only a very small percentage of everything that ever existed has been preserved, we cannot afford to waste anything. In this work, 10 case studies are presented in which exceptionally badly preserved fossil assemblages have shed light on various stratigraphic, geodynamic, paleoecologic and even phylogenetic issues. Most include invertebrate fossils from the Ordovician of Portugal, but Devonian microfossils and Carboniferous fossil plants are also discussed. In a light-hearted way, it is intended to increase the number of exceptionally badly preserved fossils watchers and to raise awareness to this negative bias of favouring "good fossils" and neglecting "bad" ones. Not least because there are no bad fossils. We have enough biases in Palaeontology already, let's not be responsible for creating one more.





## THE CRETACEOUS AMBER FROM SPAIN: 25+ YEARS OF DISCOVERIES

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### Keywords

Mesozoic, palaeodiversity, palaeoecology, taphonomy, arthropods



Ricardo Pérez-de la Fuente is a palaeobiologist focussing on fossil arthropods – namely insects and arachnids– and their ability to shed light on past terrestrial ecosystems and their dynamics in deep time. Although rooted in morphology and systematics, his work seeks to extract palaeoecological, palaeoethological, and taphonomic data. He obtained a BSc in Biology, an MSc in Palaeontology, and a PhD in Earth Sciences at the University of Barcelona. Ricardo then was a postdoctoral fellow at the Museum of Comparative Zoology (Harvard University) from 2013 to 2017, where he led the digitisation efforts on the F. M. Carpenter collection, one of the premier fossil insect collections worldwide. In 2017, he became a Museum Research Fellow at Oxford University Museum of Natural History ([www.oumnh.ox.ac.uk](http://www.oumnh.ox.ac.uk)), where since 2021 he is the current Deputy Head of Research.

Amber, fossilised plant resin, offers an exceptional glimpse into the past. A multidisciplinary, international team jointly led since 2014 by the Universitat de Barcelona and the Instituto Geológico y Minero de España (IGME) has been excavating and studying the Cretaceous amber-bearing deposits from Spain, their associated amber, and their palaeobiological content for more than 25 years. Cretaceous amber has been discovered in more than a hundred localities across the Iberian Peninsula; only a tenth of these have provided amber containing macroscopic biological inclusions, but some in remarkable abundance. Amber is unearthed using different methods and, after its preparation and study, samples become deposited at official institutions according to the province where the amber is found. Amber deposits and their associated amber are studied from the stratigraphic, sedimentological, physicochemical, taphonomic, palaeontological, and palaeoecological standpoints, among others. Palaeontological research revolves around plant (palynology, meso- and macroremains) and arthropod fossils. Two of the most successful lines of palaeoecological research based on amber inclusions focus on plant-insect relationships, such as pollination, and arthropod-vertebrate interactions. The team also carries out taphonomic experiments in resiniferous forests, and actively promotes the public dissemination of results through exhibitions, educational materials, and digital engagement. Spanish amber has already become a noteworthy source of data on terrestrial ecosystems from the late Early Cretaceous (110–105Ma), during a time of profound biotic change on land, but it has the potential to keep providing valuable information and significant new discoveries for years to come.





## ROMANIAN JURASSIC FLORAS

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### Keywords

Jurassic, coal floras, clastic floras, Romania



Prof. Mihai Emilian Popa focuses on floras of various ages, ranging from Late Carboniferous to Late Cretaceous, from Romania, Greenland, and China. He is teaching at University of Bucharest since September 1994, with a focus on Palaeobotany, Palynology and Coal Geology. Since 2019, Mihai began teaching also at Southwestern Petroleum University in Chengdu, Sichuan. He is currently Chair of the Doctoral School of Geology, Faculty of Geology and Geophysics, University of Bucharest. His studies in Jurassic Palaeobotany began in 1990 in Anina, South Carpathians, Romania, an old coal mining center and a fossil-Lagerstätte locality for Early Jurassic continental biotas. Coal mines of the South Carpathians represented unique windows for understanding the Carboniferous, Permian and

Jurassic terrestrial environments, with Anina the jewel in the crown of the Carpathian localities with fossil floras. Opened in 1792 and closed in 2006, Anina recorded more than 120 km of underground galleries, and 1300 m in depth. Such underground mining works enabled Mihai to study coal bearing formations three-dimensionally, with precise stratigraphic and spatial collecting possibilities.

Romanian Jurassic floras range between Early and Middle Jurassic in age, occurring mainly in the South Carpathians, they are compressive and permineralized, with various degrees of preservation and with a high diversity, as they include bryophytes, pteridophytes and gymnosperms. These floras are mainly coal floras, associated with economically important Lower Jurassic coal bearing formations, but clastic floras are also recorded in Middle Jurassic formations. Bryophytes include rare liverworts, while pteridophytes include sphenopsids, lycopsids and filicopsids belonging to Marattiales and diverse Filicales, with families such as Osmundaceae, Matoniaceae, Dipteridaceae and Incertae sedis. Gymnosperms include pteridosperms, cycadopsids with Cycadales and diverse Bennettitales, ginkgopsids, and diverse conifers. The Early Jurassic primary coal generators include sphenopsids, pteridosperms and conifers, while the secondary coal generators are represented by a ternary association between a fern, a bennettitalean and a ginkgoalean. In the South Carpathians, several consistent biozones were recorded: the Assemblage zone with *Thaumatopteris brauniana* (Hettangian), the Acme zone with *Nilssonia orientalis* (Sinemurian), the Range zone with *Carpolithes liasinus* (Pliensbachian - Middle Toarcian), and the Range zone with *Brachyphyllum expansum* (Upper Toarcian - Lower Callovian). The Romanian Jurassic floras occurred on the northern frame of the Tethys realm, part of the Eurosinian floristic region, recording megamonsoonal influences. Numerous Romanian localities with Jurassic plants were recorded, with Anina (Caraş-Severin County, South Carpathians) as a fossil-Lagerstätte locality for both diversity and preservation. Anina was also an important coal mining locality, among the deepest coal mines of Europe, permitting a three-dimensional control of fossil plant collecting.





## BONE MICROSTRUCTURE AND HISTOLOGY: UNRAVELING THE EVOLUTIONARY HISTORY OF THE ANTLER CYCLE

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### Keywords

Cervidae, fossils, Miocene, organ regeneration, transdisciplinary research



Dr. Gertrud Rößner, nowadays is senior curator of fossil mammals at Bayerischen Staatssammlung für Paläontologie und Geologie (München, Germany). Her expertise is the evolution and diversity of mammals and their habitats. It is based on many years of experience in collection work, research, public relations and teaching in mammal palaeontology. Fossil teeth and bones play a dominant role in this, because they are by far the most common things left over from extinct mammals and also contain a lot of information. I am interested in all levels of biological organisation, from faunal composition and species distribution in time and space, to skeletal and dentition structure, to the microscopic structure of hard tissues and genomes. For my studies I use classic methods like comparative morphology and anatomy, taxonomy

and stratigraphy, building on these with a variety of modern analytical techniques in collaboration with other experts. The aim of my work is to integrate the results into existing frameworks of earth and life sciences and to reconstruct processes leading to modern biodiversity. One focus of my research is the group of ruminants (Ruminantia).



The unique regenerative nature of antlers, being branched and deciduous apophyseal appendages of frontal bones of cervid artiodactyls (deer), is the only example of complete organ regeneration in mammals and one of the most remarkable phenomena in vertebrates. The physiology behind is complex and synchronized with behavioral and environmental specifics. It was interpreted as an evolutionarily successive achievement of cyclic necrosis, abscission, and regeneration in cervid artiodactyls (deer) and the evolutionary origin was associated with permanent precursors. However, novel insight into growth modes of evolutionary early antlers surprisingly provides evidence against that hypothesis. Microstructural and histological studies of antlers of ten early cervid species, including the oldest known, dating from the early and middle Miocene (approx. 18 to 12 million years old) of Europe show that growth patterns and a regular cycle of necrosis, abscission and regeneration are consistent with data from modern antlers. The results indicate that primary processes and mechanisms of the modern antler cycle were not gradually acquired in multiple steps during evolution, but were fundamental from the earliest record of antler evolution. Hence, explanations why deer shed antlers have to be searched in basic histogenetic mechanisms. Accordingly, cervids always have had to cope with the periodic loss and regain of their cranial appendages, and their evolutionary history was constantly accompanied by the competition between physiological costs and socio-reproductive success. The previous interpretation that proximal circular protuberances, burrs, are the categorical traits for ephemerality is refuted.



## EXCEPTIONAL 3D PRESERVATION OF MUSCLES, ORGANS AND SKELETONS FROM EARLY JAWED VERTEBRATES FROM THE GOGO FORMATION LAGERSTÄTTE

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### Keywords

Placoderm, arthrodire, Late Devonian, organs, muscle



John Curtin Distinguished Professor Kate Trinajstic has been a researcher in palaeontology at Curtin University since 2009, first as a Curtin Research Fellow and then as a QEII Fellow. Kate's research focus is the application of synchrotron tomography, especially in the discovery and mapping of soft tissue in early jawed fishes placoderms. She works primarily of the fossils from the Gogo Formation, a Late Devonian Lagerstätte and was co-discoverer of the first evidence of live birth in placoderms and led research that showed the 3D preservation of a heart, liver, stomach and intestines in an arthrodire placoderm. Kate was awarded the Malcolm McIntosh Award for Physical Sciences, one of the Australian Prime Ministerial Awards in 2010. In 2000 she was awarded her PhD from the University of Western Australia.

The Late Devonian Gogo Formation, located in the Kimberley region of Western Australia, is recognised for the exceptional 3D preservation of fossils with both skeletal and soft anatomy. Placoderms, the earliest jawed vertebrates, dominate the fauna and it is in three arthrodire genera *Eastmanosteus*, *Compagopiscis* and *Incisoscutum* that the greatest discoveries have occurred. Paired head depressor and elevator muscles were predicted in placoderms and their presence was confirmed along with a second pair of depressor and elevator muscles that had not been predicted. A set of transverse abdominal muscles had also never been predicted for arthrodires and these discoveries show that arthrodires had more complex musculature than previously predicted.

The identification of an S-shaped heart is the first fossil evidence for the anterior shift of the heart during the agnathan-gnathostome transition, which is linked to the development of the neck and jaw muscles. Preserved organs have also provided insight into the palaeobiology of these fishes, with gut contents confirming *Incisoscutum* was an active predator. The relatively large liver and absence of a lung indicates that arthrodires relied on their liver for buoyancy similar to sharks, and also resolved a long-standing argument as to when lungs evolved in vertebrates. The combination of exceptionally preserved skeletal, muscle and organs discoveries make the Gogo arthrodires the most fully understood of all jawed stem gnathostomes.



Ice Age reflections  
Beccari Victor  
Photography Competition  
(1<sup>st</sup> Prize in Category: Vertebrate Palaeontology)





Amber is fossilized tree resin appreciated for its color and natural beauty since Neolithic times. In paleontology, the amber fossil record provides a distinctive, 320-million-year-old taphonomic mode. Because of its three-dimensional matrix and its chemical properties, amber uniquely preserves a large number and variety of organisms, terrestrial, aerial, or even aquatic of different geological periods. Amber-bearing organisms encompass a wide variety of information that is helpful in the evolutionary reconstruction of ecosystems as well as organisms. Out of all, it is important to highlight the biological interactions, such as camouflage, parasitism, herbivory, predation, pollination, phoresy, eusociality, disease transmission, mimicry, etc. that will allow us to better complete the ancient puzzle of life.

# Paleoecological implications of organisms in amber

Organiser

David Peris

Botanical Institute of Barcelona (CSIC), Barcelona, Spain



## Thematic Session



## SNAKEFLY LARVAE (INSECTA: RAPHIIDOPTERA) IN LOWER CRETACEOUS SPANISH AMBERS

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### Keywords

Mesoraphidiidae, Albian, Iberian Peninsula, morphological diversity, paleofires

Snakeflies (order Raphidioptera) are holometabolous insects characterized by an elongate prothorax and a long ovipositor in females. All life stages are predatory, including the pupal stage which actively seeks prey. Although the current distribution of this group is limited to temperate and cold areas of the Northern Hemisphere and their diversity is low (ca. 250 species), snakeflies were almost globally distributed and much more diverse in the past. Raphidioptera are represented in Lower Cretaceous Spanish ambers by one species of the family †Baissopteridae, and five species and three undetermined morphotypes of the family †Mesoraphidiidae, all of them adults. Here, we report on two snakefly larvae assigned to the †Mesoraphidiidae in amber pieces from the Arroyo de la Pascueta (upper Albian, Utrillas Group) and the El Soplao (middle Albian, Las Peñasas Formation) localities. The specimen from Arroyo de la Pascueta amber is complete and well preserved. It shows three-segmented antennae bearing two apical setae, short palps, eyes with five stemmata, clearly visible ecdysial suture, head 1.5× longer than prothorax, and abdominal segment 8 longer and narrower than previous ones. The El Soplao specimen is poorly preserved and incomplete anteriorly. Although a total of 26 snakefly larvae had been previously reported in Cretaceous ambers, they were still absent in Spanish ambers. Extant snakefly larvae are often associated with dead wood. Their presence in Spanish ambers and in other Cretaceous ambers could be probably linked to greater availability of dead wood following paleofires, which in turn have been posited as promoters of resin production and accumulation.

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## ONCE UPON A TIME IN MEXICAN AMBER – A TALE OF TWO PIDDOCKS

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### Keywords

Fossil Resins, Chiapas Amber, Pholadidae, New Taxa, Taphocoenosis



This study focuses on the fossilized piddocks from the family Pholadidae Lamarck, 1809, preserved in Mexican fossil resins. Piddocks are known for drilling into substrates such as rocks, bones, shells, corals, and xylic (wooden) material. These are typically preserved within the substrates they used to excavate. Piddocks fossils, in form of inclusions, are rare, with only two species and a few reports previously published. We examined a single piece of Chiapas amber from the Simojovel region and discovered two pholadid-like bivalve specimens within it. The larger, better-preserved specimen was identified as a possible representative of a new genus and species, while the smaller specimen was classified as a new species of *Martesia* Sowerby, 1824. The fossils come from the lower Miocene fossil resin, estimated to be between 15 and 20 million years old. The study utilized transmitted and reflected light microscopy to examine the specimens. We identified several features that differentiate specimens from other similar ones (extinct and extant taxa). Among them are, the presence and shape of an umbonal reflection, mesoplax, and other additional plates, or the occurrence of periostracum and the other characters. This discovery is a significant contribution to the limited knowledge of piddocks preserved in amber fossils and expands our understanding of the evolution of the superfamily Pholadoidea. The new findings offer an important opportunity to study the palaeoenvironment and taphocoenosis of Miocene fossil resins of Mexico. Moreover, further research on this group may provide insights into the evolutionary history and biology of these fascinating bivalves.



## FIRST WHITEFLIES (HEMIPTERA: STERNORRHYNCHA) FROM EOCENE AMBER FROM DENMARK

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### Keywords

Hemiptera, Aleyrodoidea, Eocene, Baltic amber



The Sternorrhyncha is one of six suborders of sap-sucking phytophages in the order Hemiptera and is comprised of about 19,000 nominal extant species. Many of the species in this group, such as aphids (Aphidoidea), scale insects (Coccoidea), psyllids (Psylloidea) and whiteflies (Aleyrodoidea), are of great ecological and economic importance. The family Aleyrodidae Westwood, 1840 are small inconspicuous bugs, often overlooked on the host plant despite their abundance on the lower surface of leaves. Their name “whitefly” is derived from the white appearance of adults of most species due to the deposition of wax on the body and wings. The world’s described whitefly fauna currently comprises 1,707 species belonging to four subfamilies: Aleurodicinae Quaintance et Baker, 1913, Aleyrodinae Westwood, 1840, Udamoselinae Enderlein, 1909 and Berneinae Shcherbakov, 2000. Findings of whiteflies in their fossil state are very infrequent and sole specimens have been reported from a few deposits. The oldest record of fossil whiteflies comes from the Late Jurassic and the others are reported from the Lower Cretaceous, Upper Cretaceous, Paleogene and Neogene. Inclusions of fossil insects in fossil resins are valuable sources of information and provide a window into paleoecosystems and biota. Amber, a fossilized tree resin, provides exceptional conditions for the preservation of specimens. It is able to freeze moments in the lives of insects encapsulated in the tree resin and show spectacularly preserved details of their morphology. The presented material is from Eocene Baltic amber and includes 11 adult specimens, classified as seven new species in new genus, belonging to the subfamily Aleurodicinae. All inclusions are deposited in the Natural History Museum in Copenhagen, Denmark.



## UNCOVERING THE EVOLUTIONARY HISTORY OF SCUTTLE FLY WINGS FROM THE CRETACEOUS TO THE PRESENT

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### Keywords

Phoridae, fossil, amber, wing venation, palaeodiversity

The Phoridae (Cyclorrhapha, Diptera) are one of the most species-rich and biologically diverse families of Diptera. This family has an extensive fossil record in amber and copal deposits and in Defaunation resin from the Cretaceous to the present, but very few specimens have been studied. Fossil resins are conducive to the exceptional preservation of specimens allowing observation of morphological characters in outstanding detail. The well-preserved fossils fill gaps in the fossil record, which is a keystone providing a more robust understanding of the morphological evolution and adaptations that scuttle flies have undergone over the last 110 million years. An evaluation of several new fossils and the literature concerning wing descriptions highlights problems with terminology used to define essential morphological characters. The phylogenetic analyses of extinct specimens are hindered by various wing venation nomenclatures used by authors when describing specimens. The palaeodiversity assessment within the fossil record collected from many institutions brought to light phorid specimens that have never been studied. These data will contribute to the understanding of palaeodiversity over time and the potential evolutionary pressures that this family may have undergone.





## AN EXTINCT REPRESENTATIVE OF THE “EAST GONDWANAN” GENUS *DIAGRYPNODES* WATERHOUSE, 1876 (COLEOPTERA: SALPINGIDAE: INOPEPLINAE) FROM LATE EOCENE ROVNO AMBER

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### Keywords

Beetle, Taxonomy, New Species, Fossil, Cenozoic

A new species of narrow-waisted bark beetles (Coleoptera: Salpingidae) is described from late Eocene Rovno amber (Ukraine). *Diagrypnodes* Waterhouse sp. nov. is the second fossil species of the subfamily Inopeplinae, the other being *Eopeplus stetzenkoi* Kirejtshuk & Nel, 2009 from lowermost Eocene (53 Ma) Oise amber. Adult Inopeplinae are recognisable by their strongly flattened bodies and reduced elytra which has led to their taxonomic confusion with osoriine rove beetles (Coleoptera: Staphylinidae, Osoriinae) on several occasions. Extant inopeplines occur under bark in tropical and subtropical areas worldwide (except for the present-day Europe) where they probably feed on fungi or plant material. Three extant species of *Diagrypnodes* are disjunct between Australia (southern Queensland), New Caledonia, and New Zealand, each area inhabited by one species. The new Rovno amber species is differentiated from all extant species, and all except the New Zealand species are apparently winged. The presence of *Diagrypnodes* and *Eopeplus* in Eocene Europe suggest a formerly global distribution of the subfamily with subsequent extinction and range contraction in the Western Palearctic. The ant *Lasius schiefferdeckeri* (Hymenoptera: Formicidae) preserved in the amber piece as a syninclusion is a new example of the simultaneous presence of the temperate and the cryophobic (frost intolerant) arthropods in European amber forests.





## SERPHTID WASPS IN BURMESE AMBER: CT DATA PROVIDE A BETTER COMPREHENSION OF THEIR ANATOMY

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### Keywords

Burmese amber, Serphitoidae, taxonomy, Mesozoic

Amber is a material prized in the manufacture of jewellery and in paleobiological studies, and Cretaceous Burmese amber is particularly valued for its exceptional richness in fossil organisms. Because of its transparency, amber generally provides researchers with clear views of exceptionally preserved fossils. If amber is polished, it provides multiple views of inclusions, and we consequently have an idea of the representation of these organisms in three dimensions. However, the surrounding amber is sometimes opaque or clouded with particulates that do not permit a good view of all body regions. With micro-CT scans, it is still possible to have a very good reconstruction of these insects. Digital renderings allow us to see all preserved tissues, and from every point of view. Some exceedingly thin, or low-contrast parts of the body are difficult to model with CT data, e.g., the wings, but in general the technique is a really good complement to microscopy. Using these two methods (CT scans and observations on stereomicroscope), we accessed several small or hidden morphological details on some *Serphites* specimens (Hymenoptera: †Serphitidae) from Burmese amber, like the lateral ocellus nearly touching the compound eyes. The combination of observation and reconstruction permitted a very complete reconstruction of these small extinct wasps and a slightly better understanding of their anatomy. Beyond providing details for species descriptions, some features may be phylogenetically informative at the family-level.





## HOW CAN WE RECOGNIZE A POLLINATING INSECT IN THE FOSSIL RECORD?

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### Keywords

Fossil pollinator, Gymnosperms, Angiosperms, Paleobiology, Insect-plant interactions



Pollination is the process that ensures the reproduction, survival, and evolution of plants through time, which is essential for sustaining life in ecosystems. Different external pollen vectors can carry grains to the female reproductive organs, such as wind, water, animals, or a mixture of these. Unlike today, gymnosperms dominated the land surface until the rapid diversification of angiosperms over the last 100–50 Ma. It is thought that flowering plants have interacted with pollinating insects since their beginning. The inference of insect pollination from the fossil record is the main focus of current research, especially because of findings in Cretaceous ambers. However, due to the lack of consensus on the definition of “insect pollinator” and since current pollination analyses cannot be applied to the fossil record (*e.g.*, rate of visitation to female receptive flowers), the recognition of this plant-insect relationship has been a challenge. We consider it essential to define the parameters that allow us to recognize a potential pollinating fossil insect. Therefore, we propose a conceptual definition for fossil-insect pollinator and an operational classification for fossil insects into pollinators and presumed pollinators. Thus, we have recognized pollination relationships since at least the Upper Jurassic (~163 Ma). It is evident that there is a need for more detailed studies about the development of plant-pollinator interactions that could be inferred from the fossil record and its impact on today's ecosystems.



## BITING MIDGES OF THE GENUS *LEBANOCULICOIDES* (DIPTERA: CERATOPOGONIDAE) PRESERVED IN COPULA FROM THE CRETACEOUS AMBER OF EL SOPLAO, SPAIN

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### Keywords

Mating, Behavior, Fossil, Albian, Iberia



Insects preserved in copula are rare in the fossil record. That is particularly true in compression rocks, since decoupling likely occurred while on the water surface or while sinking. Most fossil insects fossilized in a mating position are found in amber. These were trapped on the sticky resin surfaces in a very short time and their positions were often secured immediately. Four biting midges (Diptera: Ceratopogonidae), three females and a male, belonging to the extinct genus *Lebanoculicoides* — the lineage regarded as sister to the remaining ceratopogonids — have been found in middle Albian El Soplao amber (Cantabria, northern Spain). Two specimens are in separate pieces of amber but two others (male and female) are preserved together in a mating position. The first female found in El Soplao amber was described in 2011 as *Lebanoculicoides excantabris*; the new specimens are deemed as conspecific. The distal abdomens of the specimens virtually in copula are aligned and separated by only 170 microns, and the apices of the female cerci and male gonostyli only by 36 microns. They exhibit an end-to-end mating position, as typically occurs in many nematocerans. Bodies are rotated 180 degrees one to the other. This is the first instance of two insects in mating position among the collection from Cretaceous Spanish amber, which is composed of ca. 4,000 bioinclusions. Apart from this rare record of intraspecific behavior in El Soplao amber, these specimens are valuable to assess sexual dimorphism in this remarkable genus. The male specimen has well-preserved and complete genitalia, allowing for a detailed description.

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## THE FAMILY THRIDAE AS EARLY INSECT POLLINATORS OF GYMNASPERMS

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### Keywords

Insecta, thrips, amber, Albian, Spain



Extant insects are important angiosperm pollinators, transferring the male gametophyte (pollen) to the stigma conducting to the fertilization of the ovule, in an ancient symbiotic relationship in which the insects usually obtain rewards. Entomophilous pollination of gymnosperms occurred well before the Cretaceous radiation of the angiosperms, but most of the pollination by insects in extant ecosystems involve angiosperms, being the Cycadales an impressive exception. The fossil record is especially poor in direct evidence of entomophilous pollination, the most impressive of these being rare cases preserved in Cretaceous amber. We studied four thrips present in three upper Albian (Early Cretaceous) amber pieces from Spain (Peñacerrada I locality), one of them bearing a copious patch of gymnospermous pollen grains of the *Cycadopites*-type, implying direct evidence of pollination in the deep time. Most of the pollen grains detached during immersion in resin are present close to the body. These thrips belong to the extinct genus *Tethysthrips* Nel et al., 2010, in the extant family Thripidae, first described from Albian El Soplao amber (Spain) and also present in Barremian Lebanese amber (*T. hispanicus* and *T. libanicus*, respectively). The new *Tethysthrips* specimens will be described as a new species (the third of the genus). Our findings provide the second thysanopteran family identified as Mesozoic pollinators, after the family Melanthripidae based on *Gymnopollisthrips* Peñalver, Nel & Nel, 2012 specimens with pollen loads from the same Peñacerrada I amber site, and further evidences that Thysanoptera is an ancient group of gymnosperm pollen feeders.



## THE INFLUENCE OF BEETLES IN THE ORIGIN OF THE MODERN TERRESTRIAL ECOSYSTEMS

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### Keywords

Coleoptera, Angiosperms, Amber, Gymnosperms, Evolution



Beetles (Insecta: Coleoptera) and flowering plants (Angiosperms), with around 25 and 14 percent respectively of the total number of known species nowadays, are the two biggest and more diverse groups of living beings on Earth today. Their evolutionary history seems to be connected since the flowering plants evolved. Phylogenetic studies support the idea that angiosperms were ancestrally insect pollinated, and that insects have pollinated angiosperms practically the whole angiosperm evolutionary history. Beetles are not only essential pollinators today, but they were among the first insects to visit flowers, during the Early Cretaceous, being fundamental pieces in driving the successive speciation of angiosperms. In addition, it seems that the influence of other lineages of wood-borer beetles and their negative effect on the gymnosperms that dominated the terrestrial surface until then, could also indirectly favour the expansion of flowering plants throughout the Cretaceous.



## AN OVERVIEW OF FOSSIL DIPLURA (HEXAPODA: ENTOGNATHA)

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### Keywords

Campodeoidea, edaphic organisms, Entognatha, palaeoecology, Projapygoidea

Diplurans are rare in the geological record despite being among the earliest fossil Hexapoda. *Testajapyx thomasi* from the Upper Carboniferous of Mazon Creek has been the only Paleozoic representative, though recently disputed (as a stem-group japygoid), similar to other basal apterygote hexapods. This limited fossil record challenges understanding of earliest hexapod divergences and relationships. Amber preserves these tiny, delicate organisms, but until now only six fossil dipluran species were known. Living in cryptic habitats and having poor dispersal reduces their entrapment in resin, as in other soil-dwelling groups. Detailed study of new specimens in Mesozoic and Cenozoic ambers, housed in the American Museum of Natural History (New York), doubles the number of known fossil dipluran species. In the family Projapygidae, two new genera and four new species have been described from Cretaceous Myanmar amber and Miocene Dominican amber. The Burmese specimen is the oldest and apparently earliest diverging lineage in the family, preserved at the exact moment while attacking its prey (a Symphypleona springtail) with discharge from its cerci. In the family Campodeidae, the only known fossil Lepidocampinae will be described from Dominican amber, and one new genus and two new species of Campodeinae will be described from Dominican and Eocene Baltic ambers, including a bizarre new genus with a beak-like rostrum unique in Diplura. This overview provides tantalising glimpses about the evolutionary history of a group that is poorly known but critical to understanding the origin of insects.

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## FALSE SCORPIONS (ARACHNIDA: PSEUDOSCORPIONES) FROM CRETACEOUS SPANISH AMBER

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### Keywords

Albian, Arthropoda, Garypinidae, Pseudogarypidae, taxonomy



Pseudoscorpions are an intriguing and understudied group of arachnids often overlooked due to their diminutive size and cryptic habits. They superficially resemble scorpions but lack a tail and sting, and use their characteristic pedipalps (pincers) for grasping prey and defending against predators. Because of their habitat preferences (litter, bark, caves), fossil pseudoscorpions are relatively uncommon, with the majority of preserved specimens found as inclusions in amber. Most of the fossil record is restricted to Cenozoic ambers while Mesozoic records are rare or poorly described. Here, we report the first fossils of the order from Spanish Lower Cretaceous (Albian) ambers. The study is based on three specimens of various states of preservation, two in amber from Peñacerrada II (Álava Province), and the third in amber from San Just (Teruel Province). The San Just specimen consists of an isolated pedipalp that has been ascribed to the family Pseudogarypidae (extant genus *Pseudogarypus*). From Peñacerrada II amber, two new genera and species can be described from virtually complete specimens; one in the family Garypinidae showing preservation of internal tissues, and other (a nymph of unknown instar) of uncertain affinities to family level. These findings represent the earliest occurrence of the families Pseudogarypidae (superfamily Feaelloidea) and Garypinidae (superfamily Garypinoidea). Further, they provide evidence for a diverse pseudoscorpion fauna in Spanish amber and shed light on the evolution and historical biogeography of the group.

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## BITING MIDGES (DIPTERA: CERATOPOGONIDAE) FROM EOCENE OISE AMBER: FIRST IDENTIFICATIONS

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### Keywords

hematophagy, diversity, France, *Atrichopogon*, *Meloehalea*

Biting midges (Ceratopogonidae) are a diverse family of Diptera whose oldest members are found in the Early Cretaceous, generally in amber and more rarely as compression fossils. Extant adult females of several genera feed on vertebrate blood and are considered as medically important since some species act as disease vectors. In the context of studies on the origins of hematophagy, the study of their fossil representatives allows a better understanding of their biology and evolution, as older biting midges lineages are also hematophagous on vertebrates (based on their mouthparts). The Early Eocene (Ypresian) amber from Oise (Creil, Le Quesnoy, France) is of particular interest, containing a great diversity and disparity of arthropods that provide exceptional paleoecological information. At present, there is a 26-million-year fossil gap between 78 mya Canadian and 54-52 mya Fushun and Cambay ambers. More than 300 specimens of biting midges have been found in 55-53 mya Oise amber, now housed in the MNHN in Paris, but none has been described yet, making them a particularly important deposit. Here we present the first results based on the identification of seven specimens, in five amber pieces, four of them being in syninclusions pairs. This study is still in progress, and other specimens will be studied. Six were identified as the extant genus *Atrichopogon* Kieffer, 1906, extending the temporal range of the genus, as the previously oldest known specimen was found in 40 mya Baltic amber; with five belonging to the subgenus *Atrichopogon* (*Meloehalea*) Wirth, 1956, and the sixth to an undetermined subgenus. The remaining specimen is a male of an undetermined genus cf. *Eohelea* Petrunkevitch, 1957, known from other Eocene amber deposit, and further work will determine its status. None of the seven studied specimens are engorged, which limits inferences about their diet until the mouthparts are analyzed. This work allowed us to identify three morphotypes among the five amber samples studied, which would preliminarily indicate a moderate diversity of biting midges with a predominance of the genus *Atrichopogon*.





## HOW DID THEY LAY THEIR EGGS? OVIPOSITION BEHAVIOR OF COCKROACHES FROM MYANMAR AMBER

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### Keywords

Blattodea, oviposition, ootheca, insect paleobiology, Cretaceous



Order Dictyoptera (so-called “roachoids”) is an ancient insect group whose Paleozoic representatives had long ovipositors and assumably laid single eggs. A gradual shortening of the ovipositor is observed throughout the evolution of this group. In the Cretaceous, groups with both external and concealed ovipositors co-existed. The internalization of the ovipositor is related to the ability to form ootheca, a structure that encompasses the hardened case and the eggs. It is produced by the collateral glands of female cockroaches. It evolved to protect embryos from drying, predation, and infections. Here, I report oothecae attached to the body of cockroaches preserved in Cenomanian Myanmar amber and describe possible modes of oviposition of extinct cockroaches. The ancestral mode of ootheca oviposition, known from the superfamilies Corydioidea and Blattoidea, is to drop the ootheca just after it is formed. Towards an investment in parental care, the ootheca is held to increase the time with maternal protection and is dropped later on, as observed in the superfamily Blaberoidea. Finally, some representatives in the same superfamily retract the ootheca into a vestibulum formed by sternite 7, where it is completely protected from external factors. The most derived mode, known as true viviparity, is present in the small subfamily Diplopterinae and is thought to have originated during the Cenozoic, characterized by the mother giving birth to live young. The oldest definitive oothecae are recorded from Early Cretaceous localities of Yixian (China) and Crato (Brazil), as well as mid/Late Cretaceous Myanmar amber.



## THE RELEVANCE OF STUDYING COPAL AND DEFAUNATION RESIN FOR DISCOVERING EXTINCT OR THREATENED SPECIES

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### Keywords

Anthropocene, biodiversity loss, amber, copal, hotspots



While amber is a well-known and studied material, with inclusions ranging from the Triassic to Holocene, younger resins such as Pleistocene copal (2.58 to 0.0117 Ma), Holocene copal (0.0117 Ma to 1760 AD), and Defaunation resin (resin produced after 1760 AD) have been largely ignored. Yet, copal and resin preserve arthropod communities from the centuries and decades leading up to the Anthropocene, giving a unique perspective on biodiversity. These inclusions allow us to explore the biota from a different perspective than that given by historical collections, and to evaluate the biodiversity loss in fragile, hotspot ecosystems. Exploration of copal and resin has demonstrated changing distributions for some species as well as uncovered new species in resin-producing forests, collectively aiding our understanding of recent evolution during the Holocene. Holocene copal and Defaunation resin from Madagascar, Colombia, the Dominican Republic, Brazil, and East Africa, sometimes reaching ages of 36,000 years BP, are rich in arthropod inclusions. Some of these are extant species, but some of them are already extinct, at least in the immediate areas of where the copal or Defaunation resin originate. For example, the stingless bees *Axestotrigona* (*Axestotrigona*) *kitingae* and *Hypotrigona kleineri*, both in Holocene copal from Tanzania, are likely recently extinct. The jacobsoniid beetle *Derolathrus cavernicolus* was also identified in such Holocene copal. Jacobsoniidae are a species-poor family of minute beetles distributed in tropical and subtropical regions, mainly islands, and have never been reported on the African continent, despite the fact that the copal piece is only  $210 \pm 30$  years BP in age.



## NOT SUCH A DAMSEL – FIRST DAMSEL BUG (HETEROPTERA: NABIDAE) FROM THE EOCENE AMBER OF LUBLIN, POLAND

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### Keywords

Fossil Resin, New Taxa, Disparity, Palaeobehavior, Palaeoecology



A new resource of Eocene amber from the Górka Lubartowska region (Lublin area, South Eastern Poland) has been recognized. It is a group of clastic deposits accumulated in the Middle and Late Eocene. Amber accumulations are found in marine sediments associated with regressive facies. Amber found in this area brought several inclusions not reported from similarly aged amber from the Gulf of Gdańsk, Bitterfeld or Ukraine. A unique representative of the true bugs family Nabidae (damsel bugs) representing a new genus and species is identified among these inclusions. The Nabidae are members of a guild of arthropod predators found in different terrestrial ecosystems. The recently found fossil presents several morphological peculiarities, not present in modern nabids, as stalked eyes and fossula spongiosa developed on all legs. Analysis of morphological features of a new damsel bug brought some indications to its palaeoecology, palaeobehavior and palaeohabitat. We can assume it was a riparian bug, hunting near shorelines or the marginal growths near freshwater bodies, estuaries, and sea coast, similarly to modern members of the families Leptopodidae, Saldidae, Gelastocoridae. *Fossula spongiosa* is present on the fore and mid legs or only on the fore legs in most of Cimicomorpha, including Nabidae. In the new fossil *Fossula spongiosa* is present on the tibiae of all legs. The presence of this structure on all legs is usually related to peculiar sexual behavior called traumatic insemination. We assume that traumatic insemination was also a behavior present in this fossil damsel bug from the Lublin amber.



## BEYOND THE LIMITS OF LIGHT AND AGE: FINE MORPHOLOGY OF AMBER FOSSILS REVEALED BY SUPER-RESOLUTION CONFOCAL MICROSCOPY

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### Keywords

Confocal Microscopy, Airyscan, Acari, Mites, Microarthropods



Amber-embedded fossils provide unique snapshots of the Earth evolution because they are preserved with exceptional fidelity and are relatively common. There are more than 150 known amber deposits around the world, covering ages from the Triassic to the Miocene. Morphological resolution of amber fossils is often comparable with that of modern specimens, as was demonstrated by transmission electron microscopy in thin sections of amber. However, the resolution of non-destructive methods for imaging of amber fossils is limited, and the quality of preservation is rarely the reason for this limitation. At the same time, the systematics of many tiny organisms, and mites (Acari) in particular, is often based on morphological features with a characteristic size of microns, presenting a challenge for imaging methods. Recently, we proposed an improved method for non-destructive preparation of amber: polishing, hydrating and imaging of amber specimens. Here we present the results obtained by using that method in combination with the super-resolution confocal microscopy (Airyscan) in the studies of fossil mites from Eocene and Cretaceous amber. The obtained resolution is comparable to that of scanning electron microscopy, which is routinely used to study modern mites. Our results show that super-resolution confocal microscopy, in combination with specific non-destructive methods of amber preparation, provides the resolution that was previously hardly feasible in fossils and helps to reconstruct the evolution of life in great detail.

The objective of this session is to provide a forum to discuss future prospects for the conservation of Palaeontological Heritage taking into account the current state of fossils protection worldwide. We encourage potential collaborators to share their experiences and opinions about the needs, barriers and disadvantages that they face in their different countries when protecting their Palaeontological Heritage and how is framed within the Sustainable Development Goals “SDGs” of UNESCO’s 2030 agenda. Since different countries have implemented different criteria and conservation laws at a global, regional or local level, it will be interesting to know the coincidences and differences between the distinct points of view. Finally, we invite potential speakers to share their strategies aimed to include the general public in effective medium- and long-term conservation plans.

# Palaeontological heritage. Future perspectives

## Organisers

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## Thematic Session



## THE PROTECTION OF PALEONTOLOGICAL HERITAGE IN MEXICO, AN ANALYSIS FROM THE INAH

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### Keywords

Fossil Record, Interdisciplinary, Biocultural Heritage, Heritage Education, Legislation

In Mexico, palaeontological heritage has had a legal framework since 1986. The Institution in charge of its application is the National Institute of Anthropology and History (INAH for its acronym in Spanish). After almost three decades, the INAH through the Palaeontology Council (ConPal for its acronym in Spanish) begins to implement the tools for the application of the legal framework. Six years after the installation of the ConPal in its new stage, and after establishing specific lines of action that involve the academy and the general public to know the legal framework and that fossils are part of the national heritage, we present the diagnosis of the situation in the country, within the INAH as well as in the universities and research centers. Although the legal framework is perfectible, it is necessary to recognize that requesting the changes depends on other areas of the government. Thus, ConPal considers important to continue working from education, promoting good practices in professional development and interinstitutional collaborations. As for social appropriation, it is important to adequately inform about the process of palaeontological research, and it is possible to differentiate between fiction and reality of the commercial content that exists on the subject. There is still a long way to go, but it is important to reflect and measure the work that has already been done, in order to propose other strategies that allow consolidating the protection of palaeontological heritage in Mexico.





## SPECIMENS FROM LAGERSTÄTTEN IN THE PALEOBOTANY COLLECTION OF THE MUSEO DE LA PLATA (ARGENTINA): HIDDEN PIECES OF THE PALEOBOTANICAL WORLDWIDE HERITAGE

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### Keywords

Rhynie Chert, Mazon Creek, Coal ball, Laguna del Hunco, Cerro Cuadrado



The División Paleobotánica is a department of the Museo de La Plata which was world pioneer in paleobotanical research, and houses a general collection with ca. 18,000 samples. Since the 20th century, it has been one of the most important paleobotanical repositories worldwide. For this reason, the Museo has received fossil specimens from ca. 30 countries and almost all the Argentinean provinces, by means of donation, exchange, and field trips accomplished by the department staff. Between them, there are small collections from worldwide known lagerstätten (*i.e.*, sites with fossils of exceptional quality of preservation and/or abundance). They comprise five pieces of the Rhynie Chert (Lower Devonian, Scotland), ca. 40 concretions from Mazon Creek (Pennsylvanian, Illinois, USA), 30 fragments of Coal Balls (Pennsylvanian, Kansas, USA), ca. 300 fossils from the Cerro Cuadrado Petrified Forest (Middle Jurassic, Patagonia, Argentina), and ca. 600 samples from Laguna del Hunco (Eocene, Patagonia, Argentina). Since the lagerstätten fossils offer valuable information about plant paleobiology, their availability helps to enrich the knowledge for the general public and the training of paleontology students. Except for a few samples, the rest have not been studied in detail. Given its paleontological and historical importance, we have begun tasks to enhance its value, for preventive conservation and to promote public knowledge of these pieces; including: classification of indeterminate specimens, cleaning and enclosing objects to protect them from dust, the use of desiccants to correct relative humidity, the mounting of temporary exhibitions, and the uploading of images to online platforms.



## 3D SURFACE DIGITIZATION OF FOSSILS: HANDHELD SURFACE SCANNING VS. PHOTOGRAMMETRY WITH FLASH-DIFFUSER IN A CASE OF QUICK PRODUCTION OF MODELS

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### Keywords

3D Scanning, Photography, Lighting-Contrast, Accuracy, Efficiency



A complete mounted skeleton of the stegosaur *Miragaia longicollum* (approximately half the fossil bones of MG4863, half recreated) was digitized for studies of reconstruction and biomechanics. Fast production of 3D models was a higher priority than their high definition, especially since the assembling of the full 3D skeleton required relatively low-resolution models. Initially, a handheld surface scanner was used (Sense 3D Scanner, 0.9 millimeters resolution at 0.5 meters, which combines structured light and photography) as it is capable of model production at high enough resolution immediately after scanning, but operation errors or misalignments were frequent, requiring process repetition with still subpar resulting models. Most Structure from Motion photogrammetric techniques use a LED ring flash, attached around the lens, as this illuminates the subject evenly, while regular flash creates hard shadows. For this project, flash photography with even and smooth lighting was achieved using a flash diffuser, and improved by an in-camera feature to lift exposure of the shadows (“Dynamic Range Optimization” on Sony cameras). Analogous results were achieved with built-in and external flashes, with more than one type of flash diffuser, and with DSLR cameras from entry to professional level. This methodology, combined with a relatively low number of photographs for faster processing (~130 each, ranging from limb bones to vertebrae in complexity), was the most efficient for a quick turnaround, with well-lit on focus photographs, mostly independent of external light conditions, taken in quick succession at high obturator speed, and capable of producing high-definition models, in occasions even more reliable than other lighting options.



## 3D DIGITIZATION OF THE SCIENTIFIC COLLECTION OF THE MUSEUM OF PALEONTOLOGY “ELISEO PALACIOS AGUILERA” (CHIAPAS, MEXICO)

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### Keywords

Photogrammetry, Paleontology Heritage, Render, Agisoft Metashape, Sketchfab



Scientific collections safeguard the natural diversity of a region; however, regulations governing these research sites restrict the release of materials for exhibitions and/or consultations. Therefore, many curators of collections worldwide have chosen to use different methods for 3D digitization of the most relevant specimens. Nonetheless, the application of this technology is still incipient in Mexico. Recently, the Eliseo Palacios Aguilera paleontology museum, located in the state of Chiapas, began to digitize fossils from its scientific collection, which houses 6,123 cataloged fossils from the region; of these, 72 specimens are holotypes, which consolidate it as one of the most important paleontological collections in Mexico. The 3D models of the selected fossils were obtained using high-resolution digital photogrammetry, a non-invasive and low-cost technique that allows obtaining virtual representation of high-quality and geometric precision. The Photographs were obtained using a 24-megapixel Canon camera and a 35 mm prime lens, whose color was calibrated to maintain the color fidelity of the specimen using Spider Chekr and Lightroom software. Then, rendered was made in Agisoft Metashape to obtain 3D models. The final render was imported into Sketchfab.com, standardized platform for viewing 3D models. Currently, the page (<https://sketchfab.com/MuseoPaleontologia>) has ten models from its holotype collection, four from the reference collection, and one from the historical collection. The 3D technology will allow digital documentation and safeguarding of the paleontological heritage of Chiapas, Mexico, thereby facilitating dissemination to the public and the exchange of knowledge with other researchers and institutions in the world.



## PHOTOGRAMMETRY AND DIGITAL SCULPTING AS METHODS FOR RESTORATION OF FOSSILS AND IN VIVO RESTORATION: A STUDY CASE

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### Keywords

Photogrammetry, 3D, Palaeoart, Restoration, Preservation



Three-dimensional modeling of fossils through different methods of acquisition is an applicable technique in different areas of computational palaeontology, such as visualization in virtual reality, biomechanics, bone retrodeformation, restoration of partial fossils and, as proposed here, the creation of highly accurate palaeoart, which is a vital piece in the communication of science. Using photogrammetry, we digitally recreated the partial skull and holotype of the Lower Triassic Brazilian Temnospondyli *Sangaia lavinae* (Dias da Silva *et al.*, 2006). Using Blender, an open-source software, to sculpt digitally, we were able to reconstruct the missing structures of the cranium based on its close relatives and the previous restorations of its skull. This reconstructed skull was printed in 3D and prepared with paint and artisanal methods to look like the original fossil, thus being better suited for museum exhibition than the original partial skull. Furthermore, the model was used as a basis for a 3D digital sculpture of the in vivo recreation. The soft tissues were estimated in relation to the morphology of the fossil, creating a highly accurate 3D palaeoart, which can be animated, manipulated in computer or virtual reality, and used as new data to study the specimen. 3D reconstruction should be established as part of the curation process in collections of fossils, as a way to preserve, generate new data and share scientific accurate models with researchers around the world.



## PRESENTING COMPLEX PALAEOLOGICAL DATA TO VISITORS OF THE ACROPOLIS (ATHENS) THROUGH ARTISTIC 3D RECREATIONS OF THE PAST

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### Keywords

Augmented Reality, Virtual Reality, Palaeoart, Smartphone



One of the most effective and comprehensive ways to transmit complex palaeontological data to the public is through palaeoart. In this context, we developed two interactive platforms for exploring the natural (using augmented reality) and virtual (using virtual reality) environments of Athens. The augmented reality application will be for inexpensive, commonly-available hardware such as smartphones. It will work at specific locations on the top of Acropolis hill. The Acropolis of Athens, one of the most visited landmarks of Greece, is located on the top of a hill, at the center of Attica basin, offering therefore an excellent view on Athens. The smartphones will use their video-see-through systems to overlay visuals onto the live environment and use sensors, such as digital compasses and GPS, to determine their location. The virtual reality platform will be developed for specialized, high performance, head mounted displays. Our palaeo-reconstructions will cover four geologic and two historic periods of Athens: Late Cretaceous, Late Miocene (Turolian), Early Pleistocene (Villafranchian), Early Holocene (Greenlandian), fifth-century BCE Athens and late 19th century, respectively. Those periods are well-documented in both the palaeontological and archaeological records. Our app aims to help the public engage with the past. This research was co-financed by the European Regional Development Fund of the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call Research Create Innovate (Research project: PalaeoScope; Project code: 03781).



## RURAL SCHOOL STUDENTS´S CONCEPTIONS OF PALEONTOLOGICAL AND OTHER TYPES OF LOCAL HERITAGE

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### Keywords

Primary School, Conservation, Paleontology, Paleontological Heritage, Territorial Identity, Science Teaching

Rural education has a distinctive connection with the surrounding territory, which can be used as a means of learning. So, in rural schools many of the curricular aspects are achieved by studying them in nature, which in this way becomes the textbook and motivates the students more. The context of the present research has been a rural school in the province of Zaragoza (Spain). This center works with projects, making use of local heritage and active methodologies so that students learn about and respect the local heritage. It is also important to highlight the great paleontological interest of the Autonomous Community of Aragon in terms of the diversity of fossils, which make it possible to record various events in the history of the Earth at a regional level. In this context, our aim is to investigate what conceptions the students of the center have about paleontological heritage and whether they know how to differentiate it from other types of local heritage (cultural, historical, etc.), as well as the relationship between their sense of local identity and the natural materials present in the nearby environment. The evaluation instrument has been a questionnaire introduced in a multigrade classroom from 4th to 6th grade of Primary Education. The results indicate that using methodologies that take advantage of the environment makes some students show environmental awareness. In conclusion, this study has demonstrated the importance of raising consciousness and connecting the natural dimension through education to care for and preserve the heritage that surrounds us.





## FOSSIL AUCTIONS: AN ANALYSIS OF THE MARKET OF THE LAST 12 YEARS

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### Keywords

Fossil, Market, Auction, Collection, Seller



The collection of fossils supports a flourishing market, which is largely unknown to the academic community. To contribute qualitatively and quantitatively to the knowledge of fossil market, a database focused on fossils auctioned during the last twelve years (January 2010 to December 2022) was compiled, and the results available online for more than 70 auction houses were opportunistically analyzed. Fifteen data were collected for each auctioned item, including taxonomic identification, provenance, state of preservation, estimated and realized value, museum quality, and the scientific importance of the fossil (evaluated based on our experience). A total of 10000 records were analyzed. Preliminary analysis of the data shows that most of the fossils traded came from North America (more than 35%) and Africa (more than 20%). The database also includes media-attracting auctions, such as Stan's auction (*T. rex* sold by Christie's in 2020 for approximately 30 million). Although not representative of the entire fossil market, which is also characterized by trade fairs, online shops, and physical shops (that cannot be easily studied), this type of data is public and readily available. The results of this research may be useful not only to learn more about the international fossil trade and to provide important information to auction houses, fossil preparators, and sellers, but also to better assess the economic value of fossils from an insurance point of view, which is useful information for museum and university collections. It also provides a solid basis for further study of this issue from legal and policy perspectives.



## THE PALEONTOLOGICAL PROJECT OF ALPUENTE (VALENCIA, SPAIN): A TOOL TO MITIGATE DEPOPULATION AND TO PROTECT HERITAGE

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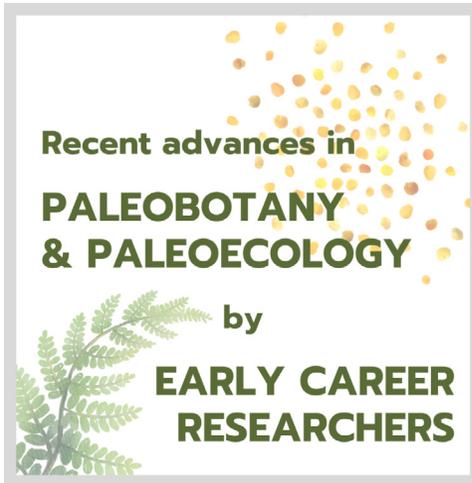
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### Keywords

Rural Development, Social Paleontology, Scientific Education, Local Museum,  
Los Serranos Region



Alpuente is located in Los Serranos region (NW Valencia Province, Spain), at the eastern part of the Mesozoic Iberian Range, an area specially affected by depopulation. The paleontological project of Alpuente began in 2001 as a rural development initiative after several field campaigns with sauropod and stegosaur remains. The results of these field works brought about the creation of several visitor-friendly paleontological spaces: the preparation laboratory, two dinosaur tracksites equipped to receive visitors and declared Items of Cultural Interest (Bien de Interés Cultural), and a local museum (opened in 2006), among others. Two aspects have been analyzed for this congress, the social and economic benefits of the project and how useful the initiative has been for paleontological heritage protection. The Museum organizes educational activities and receives thousands of visitors every year, revitalizing the village and feeding local business. Since the beginning, the Museum staff has maintained an active dialogue with local residents to encourage a broad appreciation of the value of paleontological heritage, and the positive effects of these actions have been noticed along the time. At the moment, more than twenty years later, around the 40% of the fossils in the exhibition or housed in the institution have been donated by local residents (or they have been involved somehow in the discovery) and the 56% of the catalogued dinosaur sites in Alpuente, have been located by them. Neighborhood has become a significant and active part of this project.



The aim of this session is to give visibility to the work conducted by early career researchers using fossil plant material and to provide them with a space for networking and exchanging ideas on their recent and/or ongoing research projects. The session is open to participants who currently are students (undergraduate and graduate), and to young scientists whose Ph.D. was defended less than 5 years ago, focusing on any studies that use fossil plant remains or data. We hope to include a diversity of topics, spanning various geological periods, focusing on plant organs to ecosystems, independently of preservation types and methods (e.g., anatomical description, paleoenvironmental reconstructions, phylogeny, modeling). We welcome studies using classic and new approaches, interdisciplinary studies (e.g. paleoclimatology focused), but also experimental work with applications in paleobotany/-ecology. Presentations of short studies or recently accepted projects that are still ongoing (e.g., student projects and Ph.D. chapters) are also welcome.



# Recent advances in paleobotany and paleoecology by early career researchers

## Organisers

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## Thematic Session



## PRELIMINARY PALYNOLOGICAL INVESTIGATION ON LATE MIOCENE TO QUATERNARY SEDIMENT SAMPLES FROM BOREHOLES IN BRUNEI BAY, BRUNEI DARUSSALAM

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### Keywords

Palynology, Quaternary, palaeoenvironment, Brunei, mangrove



The Malay Archipelago in Southeast Asia is a hotspot of high biodiversity including Brunei Darussalam. This is due to complex migrations of vegetation in the region since the Miocene resulting in the mixing of floristic systems. Such flora can be seen in Brunei Bay in Brunei now with a mixture of mangrove, peat, and freshwater swampy forests surrounding part of the bay. Brunei Bay also provides a great inlet for fluvial and marine sediment deposition. In this study, we attempt to trace the vegetation pattern from the late Miocene onwards based on palynological findings obtained from 5 boreholes with a ranging depth of 10 to 88 meters (known as boreholes NBH 68, NBH 108, NBH 139, NBH177, and NBH 258) stretching across Brunei Bay (Brunei side) area. A standard palynological analysis was conducted with 37 subsamples selected from the boreholes.

The findings reveal a total of 331 pollen specimens; with 18 families and 22 taxa. Rhizophoraceae, a type of intertidal to coastal mangrove, was found to be the most common family identified, followed by Fagaceae, a member of swampy and mountainous assemblage. The highest number of specimens was recorded in the deepest borehole containing mostly mangrove assemblages, while the least number of specimens with less than 10 specimens was found in much shallower and landward boreholes. These findings suggest that Brunei Bay underwent significant palaeoenvironmental changes, with mangrove vegetation with the occasional occurrence of swamp and mountainous vegetation dominating the coast in the past.



## THE BIRTH OF THE MODERN WORLD: PLANTS AT THE JURASSIC-CRETACEOUS TRANSITION

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### Keywords

Macroevolution, Fossils, Total-Evidence, Phylogeny, Disparity

The transition from the Jurassic to the Cretaceous period was a significant moment in the history of life on Earth, marked by the rise and diversification of flowering plants. However, the debate on the causes and context of this event is still ongoing. It has been suggested that the rise of angiosperms was driven by the competitive superiority of angiosperms over gymnosperms, leading to the dismissal of the previous gymnosperm-dominated floras. However, the evolutionary trajectories of the gymnosperms during the Jurassic-Cretaceous transition have not yet been formally investigated. Here, I present investigations on the dynamics of two groups of gymnosperms, namely cycads and Gnetales, during the Jurassic-Cretaceous transition. I show the presence of both similar and different patterns between the groups, with both lineages showing signs of a Cretaceous radiation and geographical expansion, but with the Gnetales showing a post-Early Cretaceous bottleneck. These results suggest some common trigger or cause of plant radiations across the seed plants, though the possibility of a common bias in preservation should be investigated further.





## FIRST PRIDOLIAN LAND PLANTS FROM WESTERN ARGENTINA

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### Keywords

Silurian, Rinconada Formation, eutracheophytes, Precordillera, Gondwana



The terrestrialization of plants is one of the most significant biological events in the history of the Earth. It is thought to have occurred during the early Paleozoic Era, as evidenced by spores, reproductive structures, and probable stomatal complexes. While the record of early vascular plants in Argentina is well-documented in Devonian-age successions, Silurian land plants fossils are scarce and limited to the northwest of the country. This contribution presents the first record of Pridoli-aged megaflora from Argentina, found in the Rinconada Formation, an olistostromic succession in the Eastern Precordillera of San Juan province. The age of the fossil assemblage is established by the presence of the graptolite *Skalograptus parultimus*. The paleofloristic taphocenosis made up of an association of eutracheophytes (*Salopella* cf. *marcensis*, *Hostimella* sp., *Aberlemnia caledonica*, *Cooksonia* cf. *paranensis*, *Cooksonia* cf. *pertoni*, *Isidrophyton* sp.), distributed in the mélange matrix. The high paleolatitude location at the Silurian-Devonian boundary of the Rinconada Formation flora has paleobiogeographic significance, given its proximity to the South Laurussian-Northwest Gondwanan phytocorion.



## NEW INSIGHTS ON THE ARCHITECTURE AND DEVELOPMENT OF THE EARLY CARBONIFEROUS PLANT *CLADOXYLON* (CLADOXYLOPSIDA)

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### Keywords

Palaeobotany, Palaeozoic, Ferns *s.l.*, Anatomy



Cladoxylopsids are an extinct group of plants known from the Middle Devonian to the early Carboniferous. Their youngest representative is *Cladoxylon*, a genus found predominantly in Tournaisian (early Mississippian, ca. 360-345 Ma) localities of Europe. While most cladoxylopsids described to date have been reconstructed as trees, *Cladoxylon* has been hypothesised to have had a non-self supporting, possibly lianescent habit. In this study, we analyse the anatomy of 50 permineralized stems from the Lydienne formation in southern France to investigate in more detail the architecture and development of these plants. The specimens are 6.5–30 mm in diameter and up to 9.5 cm in length. They have a dissected stele, with 6 to 16 xylem ribs. Protoxylem strands are mesarch, located at the rib tips, and contain parenchyma cells surrounded by protoxylem tracheids. All the specimens have secondary xylem, often more developed towards the centre of the stem. The cortex is made of two conspicuous zones, one parenchymatous and one sclerenchymatous more peripherally. Differences between the specimens include (1) the shape and number of xylem ribs, (2) the presence/absence of central vascular bundles, and (3) the mode of emission and the anatomy of second order axes. Three taxa already reported in co-eval deposits of Germany are recognized (*Cladoxylon mirabile*, *C. taeniatum*, and *C. taeniatum* form dubium), as well as potential new species. We discuss whether some of these different morphotypes of *Cladoxylon* may represent different developmental stages of a same plant and propose new hypotheses about the genus growth habit.



## CÂMARA DE LOBO'S LEAF-BED, A UNIQUE BUT POSSIBLY LOST QUATERNARY PLANT FOSSIL SITE FROM THE SOUTH COAST OF MADEIRA ISLAND (PORTUGAL)

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### Keywords

Historical Collections, Leaf Fossils, Macaronesia, Oceanic Islands, Tephra



On Madeira, most of the plant fossil sites are located in the island's northern sector. Descriptions of these sites were published during the 19<sup>th</sup> century, but in the first half of the 20<sup>th</sup> century, new published accounts ceased. During this period, naturalists that worked in Madeira Island came acquainted with the existence of a palaeobotanical record, when assembling fossils to complement natural history collections, such as those included in the Natural History Museum of Funchal Seminary. These fossils were never formally studied or published. Recent analysis of these forgotten specimens, nowadays included in the Madeira Botanical Garden collections, revealed a previously unrecognised fossiliferous site located in Câmara de Lobos village, on the south coast of Madeira. Hand-written labels indicate that Jaime de Gouveia Barreto (1887-1963), a canon, teacher, and naturalist, collected these fossils in August 1931 at the Convento locality, Câmara de Lobos. In total, seven specimens were found, consisting of poorly preserved leaf fossils and stem moulds. The fossils are preserved in tuff-breccia rich in pumice and are most probably associated to the 6 phreatoplinian deposits from the Upper Volcanic Complex (<1.8 Ma), that outcrop at Câmara de Lobos and along the south littoral of Madeira Island. Efforts to locate this leaf bed have so far been unsuccessful due to high density urbanization. Burial of palaeovegetation by pyroclastic material is rare in Madeira Island, but these fossils may indicate that other localities with phreatoplinian deposits have the potential to contain well-preserved plant fossils.



## FOLLOWING THE STEPS OF HEER, HARTUNG, LYELL AND BUNBURY: RECENT ADVANCES ON THE PALAEOBOTANY OF THE PORTUGUESE VOLCANIC ISLANDS OF MADEIRA AND AZORES

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### Keywords

Cenozoic, History of geology, Macaronesia, oceanic islands, plant fossils

On the 18<sup>th</sup> of January 1854 a leaf-bed was found by Charles Lyell and Georg Hartung on Madeira Island. This led to the first focused palaeobotanical publication by Oswald Heer in 1857 and later by Charles Bunbury in 1859. This chain of events and publications were crucial to trigger further research during the 19<sup>th</sup> century in the Madeira and the Azores archipelagos. However, despite their palaeobiological interest, during the 20<sup>th</sup> century, palaeobotanical aimed studies in these archipelagos became very sporadic. Contradicting this long-time tendency we started, since 2011, to explore the palaeobotany of these archipelagos, through the study of historical collections and newly collected fossils. This resulted in several unexpected new discoveries, especially in volcanic islands, that are widely believed to lack informative plant fossils. In this presentation we will summarise the work performed in the last 12 years, demonstrating that these archipelagos do have a well preserved and informative palaeobotanical record that can be useful to understand the extant flora and vegetation.





## BIOSTRATIGRAPHY AND PALEOENVIRONMENTS OF THE PIRABAS FORMATION (NEOGENE, PARÁ STATE-BRAZIL)

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### Keywords

Pirabas Formation, Miocene, palynomorphs, carbonate-siliciclastic



The Bragantina Platform is an important sedimentary section in Brazil's northeast Northern region. Most of the Neogene deposits forming this platform correspond to the rocks of the Pirabas Formation, which is characterized by carbonate-siliciclastic rocks interspersed by thin layers of greenish or dark clays and by sandstones with calciferous cement. Pirabas Formation has abundant and excellently preserved fossil records, that include: mollusks, bryozoans, corals, foraminifera, crustaceans, echinoids, fish, and sirenids. Here we study the palynology of the Pirabas Formation in the largest number of outcrops to date, examining 17 samples from eight outcrops and one quarry, aligned with the complete petrographic data of the unit. We recorded 9 species of dinoflagellate cysts, 7 spore morphotypes, 59 pollen morphotypes, 17 species of diatoms, and one species of silicoflagellate. The most abundant types (together representing 80% of the counts) are: *Zonocostites ramonae* (32.1%), *Lanagiopollis crassa* (18.7%), Foraminifera test linings (13.2%), *Polypodiisporites usmensis* (5.5%), *Spiniferites ramosus* (4%), *Psilastephanocolporites marinamensis* (2%), *Operculodinium centrocarpum* (1.7%), *Perisyncolporites pokorny* (1.4%), *Laevigatosporites tibuensis* (1.3%) and *Mauritiidites franciscoi* var. *franciscoi* (1%). We clustered the samples into two depositional groups: one group formed by the Capanema quarry, Ponta do Castelo and Fazenda outcrops, deposited in a mesotrophic shallow marine environment, with a late early-Miocene age. The second one, formed by Atalaia, Aricuru, Maçarico, and Baunilha Grande outcrops, was deposited in a mesotrophic coastal environment with nearby mangroves; these samples may date to the late middle to late Miocene.



## EOCENE PALEOCLIMATE AND YOUNG MOUNTAIN-BUILDING IN THE AUSTRALIAN EASTERN HIGHLANDS

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### Keywords

Eocene, Palynology, Chronostratigraphy, Paleoclimate, Paleoelevation



Through new palynological and chronostratigraphic (<sup>40</sup>Ar/<sup>39</sup>Ar dating) analyses we constrain the ages of important Australian Eastern Highland macrofloral sites. The Cambalong Creek site is late Paleocene (Selandian-Thanetian), with an age range of ~ 57.3–59.8 Ma as inferred from palynostratigraphy (*Proteacidites angulatus* Subzone of the Lower *Lygistepollenites balmei* Zone). The Brandy Creek, Hotham Heights and Mount Buller sites are middle Eocene (Lutetian-Bartonian), with a minimum age of  $39.58 \pm 0.30$  Ma, as inferred from <sup>40</sup>Ar/<sup>39</sup>Ar analyses of overlying basalts, and a maximum age of ~ 44 Ma inferred from palynostratigraphy (Lower *Nothofagidites asperus* Zone). The Kiandra Diggings site is early Miocene (Aquitanian), with a minimum age of  $21.67 \pm 0.26$  Ma as inferred from <sup>40</sup>Ar/<sup>39</sup>Ar dating and a maximum age of 23.03 Ma inferred from palynostratigraphy (Middle *Proteacidites tuberculatus* Zone). In the context of their revised ages, the recovered macrofloras suggest that subtropical climates prevailed during the late Paleocene (Cambalong Creek) and middle Eocene (Brandy Creek and Hotham Heights), whereas cool-temperate climates existed during the early Miocene (Kiandra Diggings). For the middle Eocene sites, there is no discernible difference in paleotemperature estimates between lowland and highland sites, suggesting relatively low (<550 m) paleoelevations for the present-day highland sites during the middle Eocene. This suggests that most of the present-day elevation (>1400 m) was produced by post-middle Eocene uplift.



## A SNAPSHOT OF LATE PLEISTOCENE IN SOUTHERN URUGUAY: PLANT MACRO-REMAIN RECORDS FROM THE ARROYO DEL VIZCAÍNO SITE

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### Keywords

Paleobotany, Palaenvironmental Conditions, Quaternary, South America



The Arroyo del Vizcaíno site is a fossil-rich megafaunal locality in southern Uruguay, dated to 33,550–33,900 cal yr BP. In addition to megafauna remains, the presence of pollen, fungal spores, plant tissues, seeds, fruits, leaves, woods, phytoliths, and diatoms have been verified. In this contribution, plant macroremains extracted from 35 samples from two sections of the fossil-bearing muddy sand bed were analyzed in order to contribute to the reconstruction of local plant communities. Although a high concentration of plant remains was recovered, few of them exhibited characteristics that allowed their identification. In all samples, a high frequency of seeds of *Aphanes parodii* (Rosaceae) and *Juncus pallescens* (Juncaceae) as well as achenes of *Soliva sessilis* (Asteraceae) and vegetative remains of Poaceae were recovered. Moreover, seeds of *Portulaca papulosa* (Portulacaceae), *Juncus* sp., *Eragrostis mexicana* (Poaceae), *Eleusine tristachya* (Poaceae), *Chenopodium* sp. (Amaranthaceae), and *Amaranthus* sp. (Amaranthaceae), fruits of *Lepidium didymum* (Brassicaceae), and megaspores of *Azolla filiculoides* (Salviniaceae) were frequently registered throughout the sections. In addition, seeds of *Polygonum* sp. (Polygonaceae), *Hypericum* sp. (Hypericaceae), *Cyperus* sp. (Cyperaceae), and Cactaceae, fruits of Malvaceae, and oospores of Characeae were identified. Most of the identified remains correspond to herbaceous plants typical of open grassland environments. The remains of *Juncus* spp., *Azolla filiculoides*, and Characeae sp. indicate the presence of water at the site. Finally, the absence of significant differences between the samples, along with the absence of bedding or other sedimentary structures as well as granulometric differences throughout the section, suggests a unique event of deposition.



## EPIPHYLLOUS FUNGI ASSOCIATED WITH THE GINKGOPHYTE *UMALTOLEPIS MONGOLIENSIS* FROM THE EARLY CRETACEOUS OF MONGOLIA

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### Keywords

Fly-Speck Fungi, Scutellum, Mesozoic Fungi, Gymnosperm Cuticles, Ascomycota

A preliminary report of fungal remains associated with different organs of the whole-plant ginkgophyte *Umaltolepis mongoliensis* is presented in this study. The fossils were recovered from lignites collected at the Early Cretaceous Tevshiin Govi Formation (~120 Ma – Aptian-Albian) in Central Mongolia. More than 200 specimens of *U. mongoliensis*, including leaves, cupules, and long and short shoots were analyzed using different complementary techniques (i.e., light microscopy, epifluorescence, SEM, and X-ray tomography renderings). Abundant nonreproductive and reproductive remains of epiphyllous fungi are associated with the cuticular surface of around 70% of the specimens. The most conspicuous and abundant structures are scattered to densely distributed scutella of thyriothecia-like ascomata at different stages of development, appressed to the cuticles of leaves. Additional remains on the leaves include 1-3-septate spores and septate hyphae, often with appressoria. Septate hyphae and ascomata also occur on the surface of cupules. Furthermore, septate hyphae are associated with the stomata of the cuticle, and the stomata appear filled with resinous organic contents that react under epifluorescence microscopy. In addition, septate and moniliform hyphae are distributed on the surface of shoots. These fungal remains are attributable to fly-speck fungi and other fungi, probable saprobic, representing different lineages of Ascomycota. This report represents the first steps in documenting the fungal diversity associated with different organs of this gymnosperm species and in the characterization of the ecological relationships between different organisms that inhabited the Early Cretaceous swamp forests of Mongolia. Furthermore, the complementary techniques demonstrate an improvement in observing different structures and features.





## PLANT MACROFOSSILS FROM THE AFTERMATH OF THE END-TRIASSIC EXTINCTION, SKÅNE, SOUTHERN SWEDEN

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### Keywords

Paleoflora, end-Triassic, Jurassic, Sweden



The end-Triassic mass extinction event (201 Myr ago) has received particular attention over recent decades since Sepkoski (1981) classified it as one of the “big five” mass extinction events in Earth’s history. In Greenland and Sweden, 80% of the species of terrestrial plants disappeared at this boundary. In the last two centuries, Triassic-Jurassic plant remains from Skåne, southern Sweden, have been collected, curated, and studied. However, the paleoflora from the lowermost part of the Helsingborg Member (Lower Jurassic: Hettangian) is poorly understood. We present a taxonomic/paleoenvironmental study of two novel plant assemblages collected from the Boserup beds (Lower Jurassic) in Norra Albert Quarry, Skåne. These successions are among the few localities that record the terrestrial aftermath of the End-Triassic extinction. Macrofloral samples were studied using macrophotography and fluorescence microscopy. Our findings show a dominance of Calamitaceae, Osmundaceae, Dicksoniaceae, Czekanowskiales, Pseudotorelliaceae, Ginkgoaceae, and Araucariaceae. This study contributes towards understanding the plant biodiversity changes in the Triassic/Jurassic paleofloras and helps assess climatic changes at that time.



## THE FIRST KUNGURIAN FOSSIL FOREST REVEALS THAT WETLAND CONIFERS THRIVED IN PERI-TETHYAN PANGAEA

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### Keywords

Athesian Volcanic Group, Limnic Carbonate, Root-System Architecture, Tropical Seasonality



In-situ fossil forests are valuable biological archives for the structure and setting of paleocommunities and the ecology of their organisms. Here, we present the first trees preserved in growth position in their embedding strata from the Kungurian (lower Permian) Athesian Volcanic Group, northern Italy, one of the most voluminous volcanic successions of Variscan Euramerica. We reconstruct the structure, rise and demise, and paleoecology of the forest, based on high-resolution documentation of facies architectures and petrography, and the paleontological and taphonomic characters of the fossil content. Generally, the fossiliferous strata record a volcanotectonically controlled base-level rise in a limnic, possibly endorheic, wetland basin from a low-relief volcanic landscape. The forest, preserved as calcified stem bases with roots, grew during a very short interval of lake-level stasis on a small deltaic sheetflood fan. The vegetation comprised trees less than 5 m tall with tabular root systems adapted to the waterlogged substrate, and was buried and destroyed by mass flows following rapid submergence. These obrution deposits yield parautochthonous woody debris providing anatomical evidence of conifers as the major elements of the fossil forest. Our results not only elucidate the root architecture of Paleozoic conifers, but they also document the ecomorphological plasticity of these plants and establish their appearance in wetlands by the late early Permian. In addition, the evidence of lake perenniality in the studied succession is the youngest known for the late Paleozoic of Europe, pointing to high spatiotemporal differentiation of late-icehouse aridification in the Euramerican tropics.



## LATE TO THE FUNERAL: PROLONGED REGIONAL CONSERVATION OF PALAEOBOTANICAL COMMUNITIES THROUGH THE UPPER PENNSYLVANIAN OF ATLANTIC CANADA

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### Keywords

Palaeobotany, palaeoecology, late Carboniferous, Carboniferous Rainforest Collapse, Atlantic Canada



The Upper Pennsylvanian and Lower Permian of Atlantic Canada record a major transition in the evolution of fossil plants, known globally as the “Carboniferous Rainforest Collapse;” one of the few major extinction events in the palaeobotanical record. This event is broadly characterized by the replacement of the arborescent Lycopsidea and Cordaitales by Mariattales and Coniferales. The floral transition is observed a global scale, but there are regional differences in the tempo and totality of floral turnover. This study explores the transition in fossil plant community structure at the regional scale, focusing on Pennsylvanian and Lower Permian localities from Atlantic Canada. Fossil macrofloral occurrence data were compiled from museum repositories and records from the published literature, representing plant fossil occurrences spanning the Lower Pennsylvanian through the Lower Permian. Species and genus presences and absences were used to conduct multivariate analyses of similarity between localities. Species occurrences shift gradually through time, in keeping both with predicted background extinction rates and the common use of fossil macroflora as index taxa. Analysis of community composition at the genus level revealed little change in average composition between time bins, but increased variance between sites within time bins. Sites with compositions similar to those found from the Lower Pennsylvanian persist throughout the remainder of the Pennsylvanian record. These results indicate that the turnover in Atlantic Canadian plant communities is delayed with respect to the global trend, with the Pennsylvanian mostly seeing a pattern of increasing diversity in plant community compositions.



Our understanding of the pattern and tempo of the initial diversification of metazoans in Early Palaeozoic times is more challenged than ever, with raising questions about the accuracy and completeness of the current sets of available palaeontological data and environmental proxies. This session, organized by the UNESCO/IGCP 735 “Rocks and the Rise of Ordovician Life” (Rocks n’ROL) primarily aims at filling the numerous knowledge gaps related to various aspects of the Ordovician diversification: obviously, data gaps within the period from the preceding Cambrian explosion to the post-Hirnantian Silurian recovery do exist, but also major regional biases in knowledge/data during the Ordovician itself, e.g. from Africa, South America, the Near and Middle East, southeastern Asia, Siberia. This session is not restricted to talks on palaeo(bio)geographic and stratigraphic gaps, but it also welcomes all presentations contributing to enhance knowledge on less investigated or poorly known aspects of Early Palaeozoic diversifications related to e.g. taphonomic gaps, reef communities, trace fossils, and the early colonization of continental environments by plants and animals.



# Filling Gaps in Ordovician Palaeontology

## Organisers

Candela Yves, El Hariri Khadija, Ghobadi Pour Mansoureh, Lefebvre Bertrand, Raevskaya Elena, Tinn Oive, Waisfeld Beatriz, and Wang Wenhui

## Thematic Session



## DIVERSITY PATTERNS AND SOURCES OF BIAS: CASE OF ORDOVICIAN OSTRACODS OF BALTOSCANDIA

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### Keywords

Ostracoda, Ordovician, Baltoscandia, Biodiversity, Bias



The beginning of Ordovician ostracod studies in Baltoscandia dates back to the middle of the 19<sup>th</sup> century. The research on ostracods from bedrock sections and erratic boulders was complemented with the micropalaeontological studies of drillcores from Estonia, Latvia, Lithuania and Poland during the 20<sup>th</sup> century. Richly fossiliferous sections and hundreds of research papers on the Ordovician Ostracoda make the Baltoscandian area attractive for studies on early evolution of this group. Several curves of the Ordovician ostracod diversity in Baltoscandia have been published, based on the data gathered from various electronic databases or directly from the research papers. Quality of the available ostracod distribution data is, however, strongly affected by common and group-specific factors: (1) uneven coverage of the subunits of the Ordovician System in monographic papers, (2) sampling effects (effects from variable thickness and accessibility of the units), (3) different taxonomic approaches (several authors did insufficiently consider Podocopa and Metacopa; effects from taxonomic splitting), (4) influence of poorly dated collections (material from poorly dated erratic boulders with very uneven stratigraphic coverage) and (5) methodological effects (influence of different collecting and preparation methods). Experience shows that the existing bias tends to be amplified by facies differentiation. The 'case of Ostracoda' is demonstrating pitfalls of a mechanistic approach at standard diversity calculations. Sources and effects from these bias should be evaluated for all groups and data quality requires special attention if changes in diversity are to be interpreted in an evolutionary context.



## NEW TYPE OF MARRELLOMORPH MOULTING BEHAVIOUR PRESERVED IN THE FEZOUATA SHALE

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### Keywords

Euarthropoda, Fezouata Shale, Ordovician, Marrellomorpha, moulting behaviour

Specimens of a new marrellid (Marrellomorpha, Euarthropoda) are abundantly preserved in the Ordovician Fezouata Shale Lagerstätte, Morocco. Amongst these are exuviae that allow the first reconstruction of marrellid moulting behaviours, the crucial recurrent process of shedding the old exoskeleton, excepting a unique in-the-act *Marrella splendens* individual. The marrellomorph moult record helps us interpret the evolution of this behaviour and its impact on the evolutionary trajectories of extant euarthropods. This also expands our understanding of this crucial characteristic in Palaeozoic euarthropods, which otherwise largely relates to trilobites. The moulting suture of the Fezouata Shale marrellid runs mediodorsally across the cephalic shield, between the mediolateral and posterolateral spines. One exceptional specimen represents a complete moult assemblage, showing a displaced posterior cephalic shield section supporting the posterolateral spines. Other specimens, comprising individual anterior or posterior cephalic shield sections, support this suture line location, which is also visible in specimens of complete carcasses. The mediodorsal suture line is alike that of the closely related *Mimetaster florestaensis*, and distinctive from the anterior-most marginal suture preserved in the *M. splendens* in-the-act moulting specimen. *Mimetaster splendens* exited the exoskeleton anteriorly during moulting, with the spines bent and emerging behind the body, while the Fezouata marrellid likely exited posteriorly and upwards. Mechanically, this is more analogous to moulting movements of clades with lobster-like bodyplans. This difference may accommodate the greater complexity of the spines of the more derived Fezouata marrellid, which may have been more difficult to extract during moulting, requiring different movements to avoid injury.





## DYNAMICS OF EARLY PALEOZOIC ECHINODERM DIVERSITY

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### Keywords

Biogeography, Paleozoic, Echinoderms, Diversity Patterns



The Paleozoic was a time of great climatic and biotic changes including several large radiations and extinctions, such as the Great Ordovician Biodiversification Event (GOBE) and Late Ordovician Mass Extinctions, that heavily impacted evolutionary trajectories of life on Earth. Coincident with these biotic events were abiotic events that, in part, drove such radiations and extinctions. The marine invertebrate record provides a robust platform upon which to test hypotheses of evolutionary dynamics, such as rates and causes of diversification and extinction. Some invertebrates have been studied in more detail than others (*e.g.*, brachiopods). Studies concerning evolutionary dynamics of Paleozoic echinoderms have primarily focused on crinoids, which have been used to estimate the dynamics of the entire echinoderm clade. However, this masks true patterns of diversity throughout this time. We constructed a large dataset including all major echinoderm groups (*e.g.*, taxa within blastozoans, crinozoans, echinozoans, homalozoans) spanning the Cambrian to Devonian, to quantify evolutionary dynamics. First and last appearance dates and location data (*e.g.*, formation, basin, country) were collected from peer-reviewed literature and the Paleobiology Database. Using these data, we calculated diversity, origination, and extinction metrics of echinoderms. Results indicate several turnover events, with diversity increasing slowly from the Cambrian until the Middle Ordovician. Within the Middle Ordovician, there was a notable two-stepped increase in diversity, corroborating other studies identifying the main pulse of the GOBE. These patterns of evolution will be further explored here, and their abiotic forcings investigated, by plotting geochemical datasets along recovered patterns of evolution, extinction, and diversification.



## THE PRESENCE OF THE *HOLMOGRAPTUS SPINOSUS* ZONE (MIDDLE ORDOVICIAN). SCARCE RECORDS AND RESTRICTION TO THE PRECORDILLERA OF ARGENTINA

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### Keywords

Graptolites, Olistoliths, Darriwilian, Rinconada Formation, Eastern Precordillera

This contribution introduces a Middle Ordovician graptolite fauna present in olistolithic blocks, embedded into the Silurian–Lower Devonian Rinconada Formation matrix, Chica de Zonda Range, Eastern Precordillera. These olistoliths are also characterized by marlstones and mudstones, found isolated or succeeding to hectometric limestone blocks referred to the San Juan Formation. The graptolite fauna is composed of *Holmograptus spinosus*, associated with *H. bovis*, *Cryptograptus schaeferi*, *Paraglossograptus tentaculatus*, *Archiclimacograptus* spp., *Atopograptus* sp., *Pseudophyllograptus* sp., and *Tetragraptus* sp. *Archiclimacograptus* and sinograptids are the dominant forms in the assemblage; *P. tentaculatus* is scarce and is usually found fragmented. On the bedding planes, several specimens of conodonts and trilobites are observed. The discovery of this fossil assemblage allows to record the middle Darriwilian *H. spinosus* Zone, meaning the third register of this biozone in Precordillera. The graptolite association was previously found in the upper levels of the Gualcamayo Formation, Villicum Range section; and in quartz-arenite olistoliths previously described in the Rinconada Formation as a ghost unit. Moreover, a global correlation is possible with outcrops from North America, Australasia, and equivalent levels from Scania and China. The discovery of the *H. spinosus* Zone in two lithologically different olistoliths (quartz-arenite and black shales) within the same olistostrome suggests a bathymetric-paleoenvironmental contrast between these contemporary deposits (*i.e.*, black shales deposited in a deeper location of the basin). A precise comparison of these graptolite assemblages might provide new information about this hypothesis.





## ECHINODERM LAGERSTÄTTEN FROM HIGH-LATITUDE GONDWANA: FILLING GAPS IN THE ORDOVICIAN DIVERSIFICATION OF THE PHYLUM

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### Keywords

Echinoderms, Lagerstätten, Ordovician, Palaeobiogeography, Taphonomy

Since their first appearance in the Cambrian, echinoderms constitute a major component of marine ecosystems. In the Ordovician, the exploitation of new ecological niches triggered an exponential diversification of the phylum leading to its highest morphological disparity and class-level diversity of the whole Phanerozoic. However, the precise spatio-temporal patterns of the Ordovician radiation of echinoderms remain poorly known, mainly because of strong geographical and taphonomic biases. Over two centuries, the sampling effort was mostly focusing on faunas from Europe and North America, thus providing a wealth of information biased towards crinoid-and/or blastozoan ('cystoid')-dominated low-latitude assemblages from Avalonia, Baltica and Laurentia. Another difficulty with echinoderms is that, within a few hours to days after their death, their multi-element endoskeleton totally disarticulates into many calcite plates, which can often only be identified at class level. The preservation of articulated skeletal remains of echinoderms thus requires exceptional taphonomic conditions and, generally, their burial within obrution deposits. Such echinoderm Lagerstätten provide invaluable snapshots on past communities and, sometimes, on biotic interactions. The recent discovery of several echinoderm Lagerstätten in the Ordovician of the Czech Republic (Barrandian area), France (Armorican Massif, Montagne Noire) and Morocco (Anti-Atlas, Meseta) helps partly fill the gap in knowledge of high-latitude Gondwanan faunas, and further demonstrates these were dominated by blastozoans, ophiuroids and stylophorans, and thus taxonomically distinct from lower-latitude assemblages. New echinoderm Lagerstätten bring also unique information about skeletal morphology and sometimes (soft) anatomy, which helps bridging taxonomic and phylogenetic gaps, and thus elucidating evolutionary patterns through time and space.





## HUSSEY'S GIANT CEPHALOPOD

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### Keywords

Ordovician, Cephalopod, Endoceras, Richmondian, Michigan



The Late Ordovician Richmondian Invasion is a sudden change in midcontinental Laurentian biogeography and niche occupation. Continental Laurentian plates moved tectonically from temperate to tropical/equatorial latitudes. This tectonic shift, along with uplift of the Kanakee and Cincinnati arches and the Taconian orogeny, created a warmer, deeper Michigan basin. Tropical organisms colonized these previously cooler, shallower waters over a 500,000-year period. These included apex predators like large ectocochleate cephalopods. Increase in size diversity of Richmondian cephalopods is evident in North America, even if their overall paleoecology is not well understood. Our previous work demonstrates evidence of > 1.5 m long cephalopods in the Trentonian (upper Mohawkian epoch) and Richmondian (Cincinnati stage) rocks but not in the Black River (mid-upper Mohawkian epoch). Yet early-mid 20th century investigations of the Black River rocks of the Michigan Basin hint that > 1.5 m long cephalopods may have been present. University of Michigan geology professor Russell Hussey alleged the discovery of a giant cephalopod fossil from the Escanaba River Basin (where outcrops pre-date the Richmondian). This specimen was never collected or described, despite its existence repeatedly asserted in published reports. Given its age, and because 2-3 m long cephalopod fossils have been found in nearby younger rocks, Hussey's fossil may have bridged gaps in knowledge around the paleoecology of apex predators prior to the Richmondian Event. It may have also provided information on the paleobiogeography of these animals: it would have occurred west of large cephalopod finds in Northern Michigan and east of finds in Iowa and Wisconsin. Archives and museum research were unsuccessful in rediscovering Hussey's personal papers or field notes that could have shed more light on this specimen; only additional fieldwork will clarify the tempo of cephalopod size increase in the Michigan Basin.



## WHY ARE THERE NO GIANT SPONGES IN THE BIG HILL LAGERSTÄTTE?

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### Keywords

Lagerstätte, Ordovician, Cincinnati, Aulacera, Michigan



The Upper Ordovician rocks of the Michigan Basin contain fossils common to similarly rocks elsewhere in North America. Within the series, the Big Hill Lagerstätte contains examples of preservation and biodiversity that are exceptional compared to most other localities in the Ordovician of the region. Early paleontological investigations in the Big Hill Formation report *Aulacera* (a calcified stromatoporoid sponge) and other reef building organisms from outcrops in the type section, but not in the Lagerstätte itself despite their proximity to one another. While subsequent reconnaissance was able to locate fossils of this genus *ex situ*, fieldwork has failed to recover additional occurrences of aulaceratids, or any other sponge species in either the Big Hill Lagerstätte, the adjacent type section for the formation, or nearby localities where they were once reported. Possible explanations for this absence could be an interpretation of the Lagerstätte and the type section as a tidal flat deposit, meaning that nektonic organisms likely washed in from offshore (something unlikely for the heavily calcified *Aulacera*) or that *Aulacera*'s association with corals in the prose of early studies led to their unintentional inclusion in local faunas despite being absent. Nearby, the Stonington Formation preserves such a more offshore habitat including apparent reefs, but it is not clear if it is the same age or older than the Big Hill Formation. While some organisms appear in both units (such as mobile nektonic cephalopods like *Endoceras fulger* and cf. *Gorbyoceras* sp.), each formation has an otherwise distinct fauna. Large sponges like *Aulacera* appeared to be important to the Big Hill Formation's ecology at one point in the history of research in this area, but their current stratigraphic extent, their relationships to other Ordovician organisms and ecosystems, and the actual location of *Aulacera* communities in the Michigan Basin are unknown.



The Paraná Basin is the largest sedimentary unit in South America, covering an extensive area of the territories of Brazil, Uruguay, Paraguay, and Argentina. From a paleontological perspective, the basin is historically known for its great fossiliferous potential, with organisms from the Ordovician to the Cretaceous, documented in different preservational patterns, within a range of depositional environments. Based on this, the objective of this session is to promote a space for the dissemination and international recognition of the palaeontology of this basin, encompassing different aspects of its taxonomy diversity, taphonomic histories, palaeoecological data, biostratigraphic markers, and Lagerstätte-type deposits. The session is open to all those who are interested in the theme, from undergraduate students to professional researchers, in order to encourage a rich exchange of information on advances in fossil research in the Paraná Basin.

# Palaeontological scenarios of the Paraná Basin

Organisers

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## Thematic Session



## PALEONTOLOGICAL RECORD IN THE PARANÁ BASIN: A WINDOW FROM THE ORDOVICIAN TO THE CRETACEOUS OF BRAZIL

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### Keywords

Paleoecological scenarios, Western Gondwana, Paleozoic, Mesozoic



The Paraná Basin is an intracratonic basin on South America, recorded in Brazil, Uruguay, Paraguay, and Argentina, with a total area around 1.5 million Km<sup>2</sup>. In Brazil, the basin was represented by 6 Sequences: Rio Ivaí (Ordovician-Silurian), Paraná (Devonian), Gondwana I (Pennsylvanian-Early Triassic), Gondwana II (Middle-Late Triassic), Gondwana III (Late Jurassic-Early Cretaceous) and Bauru (Late Cretaceous). At Rio Ivaí Sequence, there are sandstones, diamictites and shales, with ichnofossils, marine invertebrates and microfossils, featuring a fluvial-coastal to glacial, and finally shallow to deep platform paleoenvironments. The Paraná Sequence corresponds to sandstones with ichnofossils, shales and fine-grained sediments, rich on marine invertebrates, corresponding to a fluvial-coastal transitioning to a shallow/deep platform paleoenvironments. Gondwana I includes the thickest sedimentary record of the basin, corresponding to a glacial paleoenvironment, transitioning to a marine, and finally fluvial/eolian of a continental context. On this sequence, is recorded ichnofossils with glacial influence, coal deposits, beyond fossils with biostratigraphic importance, as mesosaurids. There are also many vertebrates, as fishes and tetrapods, flora, macro and microinvertebrates. Gondwana II corresponds to fine-grained sediments associated to a fluvial-lacustrine paleoenvironment, where herpetofauna is the most abundant. On Gondwana III, sandstones are present on the base of the sequence, with many vertebrate ichnofossils. This sequence ends with the Serra Geral magmatism. Bauru Sequence has fluvial-eolian sediments represented by many vertebrate fossils, specially dinosaurs, and the first pterosaurs described to this basin. This knowledge of Paraná Basin fossils provides rich information for paleoecological and biostratigraphic studies throughout the Paleozoic and Mesozoic of western Gondwana.



## REVISITING MESOSAURID DATA OF THE IRATI FORMATION, PARANÁ BASIN

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### Keywords

Mesosaurid, fossils, Irati Formation



The Irati Formation is a Permian unit of the Paraná Basin known for its rich record of mesosaurids, with precious data on the history of amniotes. Here we analyze this unit in order to highlight the biostratigraphic, paleoecological, and biogeographical implications of these fossils. These mesosaurs were a group of Sauropsids that lived during Permo-Carboniferous, possibly one of the first amniotes with aquatic habit. This is indicated by pachyosteosclerosis observed in ribs and vertebrae, as well as skeletal adaptations such as the paddle shaped limbs, temporal fenestrae in the skull, long and compressed laterally tail, their long snout with pointed teeth, which would form a filtering apparatus to capture crustaceans. The fossils were preserved mainly in marls, shales and limestones. Although there are three known genera of mesosaurid, their taxonomy was recently reviewed, therefore *Braziliosaurus* and *Stereosternum* are believed to belong to *Mesosaurus* taxa. Their habitat, the Whitehill-Irati Sea, was relatively shallow and while the surface water was well-oxygenated, the deeper layers were colder and almost anoxic. The associated fauna included different species of fish, sponges, crustaceans, and brachiopods. Mesosaurid remains can occur in large quantities, under different taphonomic grades, often indicating mass mortality associated with severe storm events that were possibly the cause of death, followed by burial of their carcasses. In addition to the skeletal records, some trace fossils have been attributed to swimming movements of mesosaurs in the Irati Formation, revealing more about the behavior of these vertebrates in the Permian sea of the Paraná Basin.



## THE DEVONIAN ECHINODERM LAGERSTÄTTE OF THE PARANÁ BASIN

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### Keywords

Asterozoans, Vagrant Echinoderms, Exceptional Preservation, Ponta Grossa Konservat-Lagerstätte

The Ponta Grossa Formation is a Devonian siliciclastic unit of the Paraná Basin marked by the abundance of marine fossils, mainly molluscs, arthropods, and brachiopods. However, based on the exceptional preservation of echinoderms, with organic remains and well-articulated skeletons, here we review this unit at the level of a Konservat-Lagerstätte. This echinoderm fauna comprises asterozoans, stylophorans, and pelmatozoans in several taphonomic patterns, but with a good record of vagrant forms, such as asteroids and ophiuroids. These conservation beds can be divided into two intervals within the formation based on their taphonomic, sedimentary, and palaeoecological attributes. The Interval A covers a late Pragian sequence, at the base of the Jaguariaíva Member, defined by obrutionary stagnation shales rich in trilobites and rhynchonellids, where asterozoans (*Paranaster crucis* and *Encrinaster pontis*) can be also preserved intact. Pyritization may be common in these sediments, indicating calm ocean beds and anoxia just below the water-sediment interface. In turn, the Interval B consists of a late Emsian sequence, at the base of the São Domingos Member, marked by obrution mudstones with bivalves, bryozoans, gastropods, linguliforms, tentaculitids, and plant remains, besides the notable presence of articulated asterozoans (*E. pontis*, *Marginix notatus*, and *Magnasterella darwini*), sometimes with pyritized-kerogenized soft tissue. This last interval is the climax of echinoderm preservation in the Ponta Grossa Formation, pointing to muddy seafloors frequently disturbed by storms and river discharges. Such deposits are a great window into the past, expanding our knowledge about the ancient echinoderm biota along the polar epicontinental seas of Gondwana.





## LINGULIFORM BRACHIOPODS OF THE UPPER ORDOVICIAN (HIRNANTIAN) OF THE PARANÁ BASIN, BRAZIL

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### Keywords

Brachiopoda, *Kosoidea australis*, linguliformeans, Gondwana, Iapó Formation

The first records of brachiopods from the Ordovician-Silurian periods in the Paraná basin of Brazil date back to the late 20<sup>th</sup> century. The Alto Garças, Iapó, and Vila Maria formations represent this time interval, and studied outcrops are located in the N-NW portion of the basin, in the Brazilian Midwest. While only ichnofossils have been found in the Alto Garças Formation, the latter two formations bear macro and microfossils of different invertebrates, such as brachiopods, mollusks, ostracods, scolecodonts, and trilobites. Most of the brachiopods are found in the upper part of the Iapó Formation, which is considered to be of Hirnantian age. Although the brachiopod fauna consists of both articulate and inarticulate taxa, the fossil assemblage is dominated by the Discinidae species *Kosoidea australis*. While indeterminate lingulids, obolids, and rhynchonelliformeans are also found in the same section, they are rare in comparison to *K. australis*. Inarticulate specimens were primarily preserved as molds and casts, with their morphological characters such as the shell outline, pedicle track, and growth lines easily distinguished. Micro ornamentation features were also visualized in *K. australis* individuals. Articulate specimens, represented by rhynchonelliformeans, are even rarer and were preserved as molds and impressions. The *Hirnantia* fauna reported from different places around the world consists mainly of rhynchonelliformean brachiopods, although Hirnantian discinids were also described in localities such as Argentina and South Africa. The Hirnantian brachiopod assemblage in the Brazilian Paraná basin differs significantly from the traditional *Hirnantia* fauna, and thus cannot be directly compared to it. Evidence suggests a highly endemic, context-related assemblage.





## IDENTIFICATION OF *AUSTRALOSPIRIFER* PALEOCOMMUNITY IN THE DEVONIAN PONTA GROSSA FORMATION (PARANÁ BASIN), PARANÁ, BRAZIL

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### Keywords

Devonian, Clusters, Paleoecology, Brachiopod, Paleoenvironment

The Devonian sedimentary succession of the Paraná Basin in Ponta Grossa, Paraná State, is part of the Ponta Grossa Formation (Devonian I Sequence). The unit records an endemic fauna dominated by benthic marine invertebrates. Represented from base to the top by the geological profiles Bosque Mistral, Francelina, Campus, Curva II, Curva I and Franco da Rocha, the succession constitutes a Transgressive System Tract, capped by a Maximum Flooding Surface. The *Australospirifer* paleocommunity in massive silty facies yielded Rhynchonelliformea brachiopods (*i.e.*, *Australospirifer* and *Australocoelia*) apparently *in situ* (*i.e.*, in life position) associated with trilobitomorpha and mollusks. Arthur James Boucot proposed this paleoecological association in 1971 without applying taphonomic investigations, which were uncommon at that time. Consequently, since detailed taphonomic analyses were missing what was originally visualized may not configure an *Australospirifer* paleocommunity, as proposed. In addition, fragmented and disarticulated bioclasts that conceivably have experienced possible lateral transport and some residence time at the sediment-water interface, as well as the presence of species that did not co-evolved in time were also interpreted as part of the paleocommunity, pointing to a potential temporal mixing (*i.e.*, a time-averaged paleocommunity). Recently field observations and interpretations, as well as laboratory analyses indicated a feasible *in situ* fossil association (*i.e.*, corpus-supportive mode of life) forming clusters that showed a preference for siliciclastic-dominated, shallow waters in high-energy environments corresponding to the upper to middle shoreface. Therefore, using biostratigraphic and taphonomic data, we characterize here a probable *Australospirifer* paleocommunity from the Malvinokaffric Bioregion (Malvinokaffric Realm).





## NEW OSTRACOD MORPHOTYPES FROM THE DEVONIAN OF PARANÁ BASIN, BRAZIL

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### Keywords

Ostracoda, Devonian, Paraná Basin

Research papers dealing with the ostracod record from the Devonian Ponta Grossa Formation of Paraná Basin in Brazil are scarce, with descriptions of only a single species, *Lapazites roesleri* Pinto & Purper. This study aims to shed light on the taxonomy of specimens from the Jaguariaíva Member present in the scientific collection of the Laboratório de Paleontologia, Setor de Ciências da Terra, Universidade Federal do Paraná, Brazil. These specimens are preserved as internal and external molds, which makes classification difficult, but they present some shell features such as lobes, sulci, velate structures, shape and size differences that can be useful in the identification. By using scanning electron microscopy, four morphotypes have been identified: and are herein designated Ostracoda gen. et sp. indet. 1, Ostracoda gen. et sp. indet. 2, Ostracoda gen. et sp. indet. 3 and Ostracoda gen. et sp. indet. 4, based both on size and morphology differences. Ostracoda gen. et sp. indet. 1 is the largest one; Ostracoda gen. et sp. indet. 2 presents reticulate surface; Ostracoda gen. et sp. indet. 3 differs from the previous morphotypes in having a bilobate pattern, while Ostracoda gen. et sp. indet. 4 is more elongated and has a smooth surface. They have also been compared with South American and South African specimens previously recorded, although it is too early to indicate which genus or species the specimens refer to. This study is useful to a better understanding of the taxonomy and paleobiogeography of South American Devonian Ostracods.





## PALEOECOLOGY OF A LYCOPSID FOSSIL FOREST PRESERVED IN GROWTH POSITION IN WESTERN GONDWANA

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### Keywords

Late Paleozoic, Paraná Basin, Rio Bonito Formation

Under unusual geological circumstances, individual plants or entire communities can be preserved in their growth position in the stratigraphic record, yielding crucial insights into paleoecology, as recorded in early Permian strata of the Paraná Basin (Rio Bonito Formation, Ortigueira municipality, south of Brazil). To access the paleoecology of this forest, we described sedimentary facies and facies associations, mapped exposed and unexposed casts using Real-Time Kynematic and Ground Penetrating Radar, and measured lycopsid diameters. The *Brasilodendron*-like lycopsid casts described in Ortigueira form a community with a lateral distribution of at least 600 m and are rooted in organic-poor soils formed from siltstones deposited in interdistributary bay areas of a tide-influenced delta. These plants present diameters ranging from 9 to 75 cm, and could reach heights of 4 to 18 m, forming small clusters (pairs or trios) spaced on average 5.1 m from one another. This spatial organization has two possible causes: the presumed reproductive strategy of the plants, which would involve dispersing megaspores within a limited distance, or a heterogeneous distribution of resources along the laterally diverse configuration of landforms in the clastic environment, leading to intraspecific competition. Density of the Ortigueira forest is on average 3000-4000 trees/ha, values greater than those observed in Carboniferous forests of paleoequatorial regions, which can be related to the reduced canopy attributed to *Brasilodendron*-like lycopsid. The burial process was a result of crevasse splay progradation into the interdistributary bay area that occurred after a major river flood event. This suggests that lycopsid occupied habitats with high levels of physiological stress and frequent sedimentary disturbances in the mid- to high-paleolatitudes of early Permian Gondwana.





## TAPHONOMIC ANALYSIS OF SPHENOPHYTES FROM THE RIO DO RASTO FORMATION, PARANÁ BASIN

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### Keywords

Rio do Rasto, Sphenophyta, Permian flora, Paraná Basin, Taphonomy

Known for its palaeobotanical content, the Rio do Rasto Formation is part of the Paraná Basin. For this study, fossils from this unit were collected in an outcrop in Cândido de Abreu, state of Paraná, Brazil, with 16 samples being selected, mechanically prepared and analyzed under stereoscopic microscope, focusing on the taphonomic details of fossil sphenophytes. This includes the presence of leaves, fossilization, fossil assemblage, disposition, size, bioerosion and fracture signs, number of nodes, internode length and internode ray continuity. A total of 32 fragments were found, mostly preserved as impressions, with 8 stems mineralized by oxides, and no leaves or complete specimens. The fossils were found in different levels of concentration, with no selection by size, and deposited parallel to the rock bedding, with no preferred direction, alongside glossopterid and pectopterid fragments, but not in samples containing bivalve or conchostraca, also present in the outcrop. There were no signs of bioerosion, but three samples had fracture markings. Fossil size varied from 0,5 cm to 3,4 cm in width and from 0,5 cm to 14,5 cm in length. Only three specimens preserved multiple nodes, 12 preserved one node and 14 did not preserve any, making the internode length hard to measure, varying from 1,5 cm to 6 cm. The continuity of internode rays classifies the sphenophytes as *Paracalamites* sp. Fossil assemblage indicates that the plants were transported and not immediately buried, in a high energy, shallow environment, due to the absence of bivalve and conchostraca.





## KEROSENE AND HYDROGEN PEROXIDE PREPARATION METHODS IN THE PERMIAN DEPOSITS OF PARANÁ BASIN

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### Keywords

Methodology, Micropaleontology, Foraminifera, Phytoclasts, Ostracoda

The main micropaleontological works in the Guatá Group of the Paraná Basin used HCl and HF to dissolve carbonate and silica. This work proposes to compare two extraction methodologies to evaluate the rock disaggregation and the preservation and quality of the recovery microfossils. To achieve these objectives, thirteen samples of sandstones, shales, heteroliths, and siltstones were collected. To prepare the samples, a solution of 20% hydrogen peroxide and another with kerosene was applied to 200g of each sample, during 48 hours, aiming to compare the recovery of microfossils and the disaggregation in each method. After preparation, the samples were washed on sieves with a mesh size between 420 and 75  $\mu\text{m}$ . The initial mass of the samples was measured before preparation, as well as the mass retained on the sieves. The disaggregation rate was calculated based on the initial mass and the mass retained on the 420  $\mu\text{m}$  sieve. These values were plotted in a scatter diagram, which indicated a strong positive linear correlation between the two methods. The recovered microfossils included foraminifera of the genera *Paralingulina*, *Thuramminoides?*, *Saccamina*, and a fusiform form. Additionally, three kinds of phytoclasts, an ostracod, and unidentified bioclasts were recovered. The strong linear correlation between the disaggregation rate indicates that probably the parameters that influence the rock disaggregation are intrinsic to its characteristics, such as porosity, permeability, or organic matter content. Regarding the recovery of microfossils, in the kerosene method, hyaline foraminifera and phytoclasts presented a better preservation, while in the  $\text{H}_2\text{O}_2$  method agglutinated foraminifera had a better recovery.





## FIRST EVIDENCE OF REPRODUCTIVE STRATEGIES IN DEVONIAN CEPHALOPODS PRESERVED IN SIDERITE NODULES FROM URUGUAY

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### Keywords

Paleoenvironments, Siderite Nodules, Goniatite, Reproductive Strategies, Exceptional Preservation

Uruguayan ammonoids have received attention because of their completeness and preservation, including soft tissues, inside sideritic nodules found at the San Gregorio Formation. This unit is mainly characterized by diamictites, sandstones and shales (rhythmites), lithologies that reflect postglacial and periglacial environments, but its age is still a matter of debate. During Middle to Late Devonian throw of the Early Permian, southern Gondwana was affected by intermittent glaciations, according to recent studies. The nodules are found inside tillites from the base of the San Gregorio Formation and preserve a marine community including actinopterygians, cephalopods (nautiloids and ammonoids), and Rugosa and Tabulata coral remains which suggests shallow and relatively warm environments. We consider the nodules as have been reworked from underlying units of Devonian age, where we also found them. The cephalopod material includes clusters of embryonic ammonoid shells (diameter less than 3 mm), all at the same stage of development, as suggested by SEM studies. They are interpreted as ammonitellas preserved in the second stage of shell mineralization, and all the ammonoids are enclosed by a structure chemically different, regarding the surrounding sediment. We suggest these clusters as being reproductive sacs, a strategy that is commonly found in recent cuttlefish, where the female protects the eggs with a mucous mass secreted by nidamental glands. Although more studies need to be done, the described materials would represent the oldest known record of ammonitellas for South America and the oldest known record of reproductive strategies in Palaeozoic ammonoids.





## UNCOVERING PALEOENVIRONMENTAL CHANGES IN THE LONTRAS SHALE FOSSILLAGERSTÄTTE OF THE PARANÁ BASIN THROUGH MICROPALAEONTOLOGICAL ANALYSIS

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### Keywords

Foraminifera, Lagerstätte, Phytoclast, Glacial-Environment



The purpose of this study was to refine the paleoenvironment of the Lontras Shale (Rio do Sul Formation, Itararé Group) based on the study of foraminifera and phytoclasts. This shale is a Carboniferous Fossilagerstätte deposited under glacial influence, located in Mafra city in Brazil. Sampling was conducted in twelve layers of the shale (1A, 1B, 1C, 1D, 2A, 2B, 3A, 3B, 3C, 3D, 4A, 4B) in a 1.2m outcrop. The samples were collected every 10cm and weighed with 600g. The collected material underwent chemical treatment with 15% hydrogen peroxide for 24 hours. Samples were then washed and dried, and all the total fractions were observed under a stereomicroscope. A total of 316 bioclasts (entire fossils or fragments) were identified. Thirty-three of the specimens were analyzed in a scanning electron microscope. After that, foraminifera and phytoclasts were identified, classified located in a stratigraphic profile. The foraminifera were identified as *Ammobaculites* sp., *Psammosphaera irregularis*, and *Saccamina* sp. The cell structures of the phytoclasts suggest they belong to conifers, possibly *Agathoxylon*. Additionally, the good preservation of the phytoclasts could relate the Lontras Shale to a proximal environment. Finally, the analysis of the microfossils suggests that the Lontras Shale Fossilagerstätte experienced significant changes in nutrient supply during deposition. The high concentration of microfossils and macrofossils in the 3D layer could indicate an increase in nutrient supply or temperature variation during the deposition of the Fossilagerstätte. Therefore, the microfossil data support that the Lontras Shales were deposited in a coastal environment such as an estuary or fjord.



## NEW TAXONOMIC CONSIDERATIONS ON THE OCCURRENCE OF THE TAXA *ANNULITUBUS* SP. FOR THE DEVONIAN PARANÁ BASIN

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### Keywords

Tubeworms, morphotype, *Serpulites*, Polychaeta, Malvinokaffric province

Among the various organisms preserved in the Devonian beds of Paraná are the tubeworms. Representing organisms from different phyla, with a wide stratigraphic distribution, taxonomic discussions have always been related to the group. The objective of this work was to perform a taxonomic revision of the group in the Devonian of Paraná Basin. In the collections of the Laboratory of Stratigraphy and Paleontology of the State University of Ponta Grossa, 277 samples of tubeworms were selected, representing 2.929 bioclasts. Previous identifications defined these fossils as ?Vestimentiferous, agglutinated polychaeta, *Serpulites* and *Cornulites*. The taxonomic review presented here used the Morphotype approach, identifying 12 distinct morphological patterns, concluding only the occurrences of *Annulitubus*, *Cornulites* and agglutinated polychaeta as valid. Morphological variations along the tube of the same individual were found in *Annulitubus* samples, being smooth in the basal portion, with shallow rings in the medial and well-marked rings in the upper portion. These three morphotypes are the same as those found in individuals previously classified as Vestimentifera (medial and upper portions) and *Serpulites* (basal portion), now reinterpreted as *Sphenotallus*. However, these specimens differ from the branched organism *Sphenothallus* by not showing diagnostic features and evidence of clonal budding. Presumably, preservational bias has occurred, where different parts of the same organism have been disjointed, classified as distinct taxa representing the same species. Consequently, specimens previously defined as *Serpulites* and ?Vestimentifera represent, respectively, basal and upper parts of *Annulitubus*, which presents morphological variations along the tube, and should not be considered different species.





## ICHTHOLOGICAL CONTENT OF THE CAMPO DO TENENTE FORMATION (ITARARÉ GROUP, PARANÁ BASIN), SOUTHERN BRAZIL

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### Keywords

Trace fossils, Itararé Group, Paraná Basin, Trails, Excavations

Trace fossils are important tools for paleoenvironmental reconstruction and provide valuable information about the conditions of ancient ecosystems. In this regard, for the first time four ichnotaxa were described in shales from the Campo do Tenente Formation, lower portion of the Itararé Group in the Paraná Basin, southern Brazil. Despite trace fossils being common and well-preserved in deposits formed during the Late Paleozoic Ice Age (LPIA), there is no records of biogenic structures in these shales in the literature yet. All the samples were collected in a quarry at Campo do Tenente, Paraná, and four different ichnospecies were diagnosed and described. *Hormosiroidea meandrica*, *Helminthoidichnites tenuis*, *Diplichnites gouldi* and *Umfolozia sinuosa* were identified in a centimetric level of shale and represent an ichnological assemblage marked myriapods trackways and burrows produced by wormlike animals. *Hormosiroidea meandrica* dominates the ichnoassemblage, followed by *H. tenuis*, *D. gouldi* and *U. sinuosa*. These new data allow the interpretation of new scenarios to evaluate the depositional conditions of bioturbated shales from Campo do Tenente Formation during the LPIA. Along with sedimentological, geochemical, and stratigraphic data, trace fossils can be useful in the construction of a more robust paleoenvironmental framework for the Itararé Group.





## NEW PALEOENVIRONMENTAL INSIGHTS FOR THE GLACIOGENIC DEPOSITS OF THE CAMPO DO TENENTE FORMATION (ITARARÉ GROUP, PARANÁ BASIN), SOUTHERN BRAZIL

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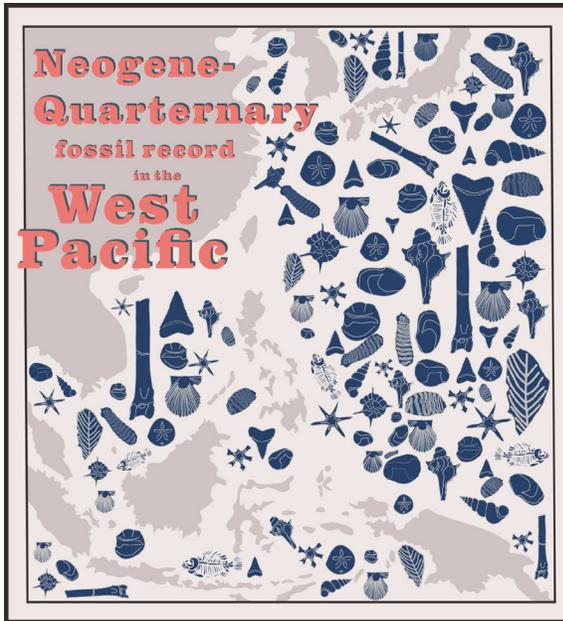
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### Keywords

Paraná Basin, Late Paleozoic Ice Age, *Scoyenia*, *Mermia*, Freshwater

The Pennsylvanian Campo do Tenente Formation (Itararé Group) in SE Paraná Basin includes mainly muddy deposits accumulated in water bodies during the Late Paleozoic Ice Age. Past paleoenvironmental interpretations point to the existence of a restricted environment influenced by brackish waters, punctuated by mass flows and bordered by glaciers. To refine this current paleoenvironmental setting, this research seeks to integrate new sedimentological and ichnological data. In the examined interval, the Campo do Tenente Formation is dominated by shales and rhythmites with ice-rafted debris (IRD) that testify floating ice in a low-energy environment. New analysis identified the occurrence of trackways and burrows, in a horizon 20 cm stratigraphically above the uppermost appearance of IRD. The trackways from *Diplichnites* and *Umfolozia* indicate movement of small arthropods in subaqueous substrate with periodic drying in shallow freshwater environments. Additionally, burrows from *Helminthoidichnites* and *Hormosiroidea* point to the existence of a benthic community. Based on these trace fossils, it is suggested the coexistence of the *Scoyenia* and *Mermia* ichnofacies, that combined with the sedimentological data allow the inference of a terrestrial low-energy ecosystem, dominated by freshwater with periodic moments of substrate exposure. The absence of dropstones in these shales suggests that icebergs no longer contributed with the sedimentation. Meanwhile, melting of ice masses present in the surroundings could be responsible for the input of freshwater. These new insights contribute to refine the paleoenvironmental interpretations for this interval, indicating possibly a more important contribution of freshwater and moments of subaerial exposure, not considered in previous interpretations.





The present biodiversity hotspot of the West Pacific region, including subtropical Taiwan-southern Japan, tropical Southeast Asia, and Australia, originated during the early Miocene through a complex geological history related to tectonic movements. The fossil record provides essential evidence of how various communities responded to these geological and environmental events that led to this biodiversity hotspot formation. The session is dedicated to presenting the rich and diverse fossils in the West Pacific. We aim to provide an international platform for discussion between paleontologists examining the factors that have driven the distribution of faunas in the region. We encourage all contributions to systematic paleontology, paleoecology, geochemistry, evolutionary biology, paleoichnology, and taphonomy. Methodological insights, including new techniques and models, are also welcome.



# Neogene-Quaternary fossil record in the West Pacific

## Organisers

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## Thematic Session



## PALAEODIVERSITY OF MARINE FISHES IN THE INDO-AUSTRALIAN ARCHIPELAGO

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### Keywords

Fish Teeth, Otoliths, Borneo, Tropics, Biodiversity Hotspot



SPOTLIGHT  
TALK



The Indo-Australian Archipelago (IAA) has today's highest marine fish biodiversity with over 2000 species. This biodiversity hotspot exists there since the Miocene as it shifted from west to east during the closure of the ancient Tethys Ocean. Many invertebrate taxa moved with the hotspot attested by the fossil record, but in the case of fishes such origin is mainly supported by molecular phylogeny, which analyses also uncovered many speciation events in the region. However, evidence from the fossil record is very sparse and in general the Southeast Asian fossil fish record is understudied. The most often reported remains from this region are shark and ray teeth, fish otoliths and bone fragments, and there are only few localities from where more complete body fossils were described. We provide a brief literature review of the so far published fossil fish material from the IAA with the first reports coming from the early explorers of the Dutch East Indies during the late 19<sup>th</sup> and early 20<sup>th</sup> centuries. Fish remains were mostly described from Java and Sulawesi, and occasionally from Sumatra and Borneo. Most of the accounts are old and the whereabouts of many of the original specimens is unknown. More recent studies from Borneo and the Philippines, and the nearby subtropical Taiwan, started revealing the high palaeobiodiversity of the region's Neogene and Quaternary fish faunas. This emphasizes that detailed and frequent field surveys, micro-sampling techniques, and involvement of local assemblages could help extending our knowledge on the IAA's hidden fish palaeobiobiodiversity.



## AN ARTICULATED FOSSIL CIDAROID (ECHINODERMATA: ECHINOIDEA) FROM THE MIDDLE MIOCENE NANGANG FORMATION IN NORTHERN TAIWAN

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### Keywords

Neogene Geology, Invertebrate Palaeontology, Echinoid Biofacies, Obruchium Deposit, Western Foothills

Cidaroids (Cidaroidea: Cidaroida) are the most primitive taxa among extant echinoids, characterized by their large primary spines. The earliest fossil cidaroids can be traced to the Triassic. This study represents the oldest occurrence of this family in Taiwan. The fossil-bearing unit is the Nangang Formation (~15 Ma) that is well known for sand dollar-rich horizons. The cidaroid specimen, however, does not occur in the same fossil beds. Two other cidaroid occurrences are associated with limestone reef systems in southern Taiwan, which are much younger (less than 3 Ma). Due to the preservation of large primary spines in the surrounding sediments, this occurrence is interpreted as an obrution deposit. The specimen was removed from its original reef settings and transported into a depositional basin via a storm event. Based on its transverse oval and confluent areoles and distinct, rod-like, spinose, primary spines, the specimen possibly belongs to the genus *Prionocidaris*. Whether the cidaroid-bearing horizon and the sand dollar-rich beds represent two distinct biofacies are yet to be determined. Nevertheless, diversified fossil assemblages within the Nangang Formation increase the potential to utilize fossil echinoids for stratigraphic correlation across different sections in northern Taiwan.





## TEMPERATURE-MEDIATED EVOLUTION OF EXTRAORDINARILY TINY ECHINOID *SINAECHINOCYAMUS MAI* (ECHINOIDEA, TAIWANASTERIDAE) BASED ON CLUMPED ISOTOPE THERMOMETRY

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### Keywords

Lilliput Effect, Climate Change, Glacial-Interglacial Cycles, Clumped Isotopes, Echinodermata

*Sinaechinocyamus mai* is an echinoid species named after Ting-Ying Ma, the first department chair of the Department of Geosciences, National Taiwan University. It is one of the characteristic sand dollars that is still living along the western coast of Taiwan and is significantly different from their closest relatives in size and biogeographical distribution. In particular, its extraordinarily tiny body size reveals unusual evolutionary paths which could be related to changing environments. Here, we examined paleoenvironmental conditions and performed conventional stable carbon and oxygen isotope and unconventional clumped isotope analyses of well-preserved fossilized samples in the past ~8 Ma. We analyzed the carbonate component of *S. mai* and the inferred temperature of the environment where it grew, by assuming the carbonate precipitation is in thermal equilibrium with the ambient. Temperature estimated from both  $\delta^{18}\text{O}$  and  $\Delta_{47}$  indicates *S. mai* is more adaptable, living in a higher and wider temperature range than *S. mirabilis* which is the closest relative to *S. mai*. We found that the clumped temperature of *S. mai* anti-correlates with its body size. Our analysis also suggests that warm climate preferentially selects small body size species, triggering the evolution and deviating *S. mai* from its ancestors which used to live in cold-water environments.





## NEW FOSSIL SPECIES OF THE GENUS *LAGANUM* (ECHINODERMATA: ECHINOIDEA) FROM THE KUEICHULIN FORMATION (LATE MIOCENE– PLIOCENE), NORTHERN TAIWAN

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### Keywords

Neogene geology, West Pacific, East Asia, Echinodermata, Echinoidea, laganids

This study aims to describe new fossil echinoids, with potential new species, from Taiwan. Following the construction of new dams in Taiwan over the past decades, late Miocene to early Pliocene strata were exposed with abundant marine fossils, including fossil echinoids. Currently, the classification of irregular echinoids is under a major revision, largely owing to new molecular data. New fossil material allows us to review the published interpretations among the genera *Laganum*, *Jacksonaster* and *Hupea*. Initial observation and statistical analysis of the available specimens (n= 93) indicate that there are two species among the collected material presented in the current study. The first has a larger body size (reach 60 mm) with noticeably higher petaloid regions. In particular, the periproct is positioned and moves toward the margin on the oral side during ontogeny. The second species is markedly smaller with less well-defined petaloid regions and a thick margin. Position of periproct in the latter is close to the peristome. In contrast to the novel data from Taiwan, occurrences of both fossil and extant species of *Laganum* from America and Asia do not overlap, and the American fauna occur in significantly older strata. Current issue(s) on systematics and palaeobiogeography of *Laganum* and its relatives are reviewed and discussed.





## DEVELOPING BASELINE DATA FOR PALAEOENVIRONMENTAL STUDIES IN SOUTHEAST ASIA USING ARIIDAE (SEA CATFISH) OTOLITHS

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### Keywords

Otolith Morphology, Lapilli, Allometry, Palaeobiodiversity

Otolith (ear stone) morphology is typically used to distinguish fish species and genera. However, for sea catfish (Ariidae, Siluriformes), it is hard to differentiate the otoliths of certain taxa especially at lower taxonomic levels due to their rather complex and almost indistinguishable morphological features. In this work, we provide information on the morphology of lapilli otoliths of several modern ariid species with the aim to study the diversity of past fish assemblages and provide baseline data for other allometric examinations. Moreover, since ariids can adapt to different environments, the appearance of certain taxa can help to assess habitat conditions back in time. This study utilizes 164 fossil Ariidae otoliths found in late Miocene deposits of Brunei Darussalam (North Borneo). Additionally, a total of 82 modern Ariidae otoliths (belonging to 10 species) were collected from various fish markets in Brunei and Bornean Malaysia. The morphological information collected from the modern otoliths was used to identify and classify the fossil otoliths. Overall, seven Ariidae species were distinguished in the fossil record, with *Nemapteryx nenga* (thickspined catfish) being the most abundant. Although the recovered taxa suggest a generally shallow marine coastal environment, the varying faunal composition among the studied fossil sites may indicate subtle environmental differences. Such disparities could be a result of coastal processes and related salinity gradient between fully marine and deltaic/estuarine brackish conditions. However, ecological conditions can be further traced in the future with geochemical analyses of the otoliths, and adaptation to different environment through time could be further explored.





## NEW FOSSIL CUTTLEBONES, SEPIIDA (MOLLUSCA, CEPHALOPODA) FROM THE LATE PLIOCENE AND PLEISTOCENE, WEST TAIWAN

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### Keywords

Cuttlebone fossils, Cephalopods, Taoyuan Daxi, Tainan Yujing, Kueichoulin Formation, Biological migration, Neogene

Squid (Sepiida, Cephalopoda) originated in the early Miocene. Most of the fossils were found around the Mediterranean Sea, and the rest were only found in India and Australia. In fact, because fossil remains of most cephalopods are difficult to survive, only the squid's inner shell, a buoyant and supporting endoskeleton, has a chance to survive. So far, apart from a few scientific reports on nautilus fossils, there are no other groups of cephalopods reported in Taiwan. We collected 15 cuttlebone fossils from Taiwan, belonging to 9 species in 3 genera. The fossil samples, ranging from medium to large in size, are similar to the recent species. Fossil occurrences are mainly distributed in Taoyuan (Northern Taiwan), Tainan (Southern Taiwan), Chiayi (Central Taiwan), and Kaohsiung (Southern Taiwan). [it probably has been illustrated in the local museum guidebooks already.] Fossil evidence shows that during the Cenozoic period, the Taiwan Strait may have been a route for squid migration, expanding from its origin to Northeast Asia.





## FAUNAL CHANGE ACROSS THE CHOLAN-TOUKOSHAN BOUNDARY IN MIAOLI, TAIWAN

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### Keywords

Quaternary geology, Western Foothills, Biostratigraphy, Benthic foraminifera

The Cholan Formation, characterized by repeated interbedded sandstone and mudstone layers, is one of the most representative Cenozoic formations in Taiwan. However, since the Pliocene/Pleistocene (P/P) boundary that coincides with the Neogene/Quaternary boundary was revised by the International Commission on Stratigraphy in 2009, the corresponding stratigraphic boundary in Taiwan is yet to be defined. During the process of searching for the new P/P boundary on land, we noticed the abrupt faunal change across the Cholan-Toukoshan Boundary (CTB). While a recent study suggested the use of planktonic foraminifera and calcareous nannofossils for defining the CTB, we observed that planktonic foraminifera is rare in the samples from the Cholan Formation. In addition, many microfossils show signs of reworking. Thus, the former boundary interpretation based on planktonic foraminifera biozones seems unreliable. Instead, the change of species composition of benthic foraminifera assemblages may be a more feasible way to define the CTB in Taiwan.





## NEW ACROPOMATID FOSSILS (PISCES, ACROPOMATIFORMES) FROM THE EARLY PLIOCENE OF KUEICHULIN FORMATION, NORTHERN TAIWAN

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### Keywords

Palaeoichthyology, Teleosts, Palaeobiogeography, Skeleton, CT Scanning, Neogene

This report presents rare remains of four individuals of acropomatid fish (including a nearly complete skeleton) from the upper Kueichulin Formation (early Pliocene) in northern Taiwan. The fossils are preserved in a form of a nodule discovered at the locality known for abundant marine crustaceans and echinoderms. These specimens can be assigned to a member of the family Acropomatidae based on their displayed characters, including dorsal fin with nine spines and about eight soft rays, anal fin with three spines and eight rays, opercle with two flat spines and typical architecture of the skull. Detailed examination and computed tomography (CT) scanning reveals the presence of “L” shaped preopercle with well-developed lobe in the postero-ventral margin of the bone and well-developed spinulations, presence of five abdominal and 13 caudal vertebrae (total numbers were definitely higher, 10 and 15 respectively) and general shape of neurocranium in various aspects. Fossil otoliths are not uncommon in the Pleistocene deposits in southern Taiwan, but this finding represents the earliest skeletal acropomatid fossil record from the region. The discovery of these new acropomatid fossils provides important insights into the biodiversity and evolutionary history of fish in the Indo-West Pacific region, particularly during the Neogene. This study highlights the importance of continued exploration and discovery of new fossil specimens to better understand the complex and dynamic history of marine life in this region.





## FOSSIL MOLLUSCS OF THE PHILIPPINES: A RECORD OF PLIO-PLEISTOCENE SHELL-BEARING SHALLOW MARINE DEPOSITS ALONG THE NORTHWEST COAST OF LUZON ISLAND, PHILIPPINES

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### Keywords

Indo-West Pacific, Molluscs, Palaeontology, Philippines, Plio-Pleistocene

The Indo-West Pacific (IWP) region has been the focus of several studies on the endemism and diversity of marine organisms due to its high species richness and biodiversity. Studying marine fossils from the IWP can give insights to the past environmental conditions and history of the biodiversity hotspot. Along the northwestern part of Luzon, specifically in the Ilocos-Central Luzon Basin, are several shallow marine deposits that host shell-bearing lithologies. Three (3) Pliocene and one (1) Pleistocene units are investigated. The Laoag Formation (late Early Pliocene to Pleistocene) in Ilocos Norte consist of sandstones composed of shallow marine sand dwelling molluscs, while the partly coeval Santo Domingo Formation (Middle to Late Pliocene) in Ilocos Sur consists of reef-associated molluscs. Further south, in the Province of La Union, are the Middle to Late Pliocene Cataguingtan Formation and the Pleistocene Damortis Formation. The former consists of an intertidal (mud-favoring) mollusc assemblage, while the latter consists of abundant small pelecypods. The limestone facies of the Damortis Formation (called the Bacnotan Limestone) contains giant clam fossils (*Tridacna*) in certain areas. Exposed along the entire coastline of northwest Luzon are deposits of uplifted coral reefs (Late Pleistocene to Holocene) which also contain abundant molluscs. The variety of assemblages in the investigated sites illustrate how distinct environmental conditions lead to different mollusc communities, which are crucial for the establishment and reconstruction of the depositional history within the sedimentary basins.





## THE INTRODUCTION OF FOSSIL RECORDS OF PODOCARPACEAE IN TAIWAN

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### Keywords

Podocarpaceae, Paleobotany, *Podocarpoxyton*, Taiwan

The unique geology and locality have nurtured the high endemism and complicated natural history of the plants in Taiwan. One of the representative plants in this regard is the gymnosperm, which contains both tropical and temperate elements. Among gymnosperms, Podocarpaceae consists of members from mostly tropical regions in Asia and Oceania. There are two genera and 5-6 species currently known native to Taiwan, including taxa in Southeast Asia and extended to northern Asia from both genera, therefore it is of interest to study the biogeographic pattern for Podocarpaceae species in Taiwan. However, the fossils of gymnosperms in Taiwan are scarce despite various efforts of paleobotanical collections in past decades, particularly for the macrofossils. However, new progress has been made with promising results recently and they would contribute to the research of the natural history of plants in Taiwan. Here we review the current records of Podocarpaceae that have been found in Taiwan, focusing on our recent finding of *Podocarpoxyton nageioides*, from the Miocene which was published in 2021, as well as some undescribed specimens from the same strata at hand. A comparison with the fossil records from nearby regions, *i.e.*, China, Japan, and the Philippines, will be speculated for the implications of reconstructing the paleoenvironment and paleoclimate in these regions according to Podocarpaceae fossils.





## NEOGENE AND QUATERNARY MARINE FOSSIL RECORDS OF THE PHILIPPINES: A REVIEW OF THE CURRENT STATUS

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### Keywords

Southeast Asia, Fossils, Biodiversity, Paleontology, Natural History



Fossils provide invaluable insights into the diversity, ecology, and evolution of life on Earth. However, some regions, such as the Philippines, have limited information on their fossil records. Here, we present an overview of Neogene and Quaternary marine fossil records of the Philippines based on published reports and articles. The specimens presented here are primarily deposited in museums and institutions for education and research. We found that microfossils, specifically foraminifera (60%), coccolithophores/calcareous nannofossils (21.48%), and radiolarians (8.68%), dominate the existing records. Mollusks (7.38%) and other fossils such as corals, fish, echinoderm, sharks, and brachiopods (1.3%) are also present. Notably, a well-preserved specimen of black marlin (*Istiompax indica*) collected from an Early Pleistocene unit from Tambac Island, Pangasinan, and deposited at the National Museum of the Philippines, represents the first fossil billfish described from Asia. Marine fossils are reported in the three major island groups of the Philippines (Luzon, Visayas, and Mindanao), with several records in the islands of Palawan, Cebu, Panay, and Bohol, and the provinces of Pangasinan, Ilocos, Batangas, Bulacan, and Nueva Ecija. However, further efforts are needed to describe the natural history of Mindanao due to the limited information in the area. We highlight the critical role of both public and private agencies in conducting paleontological studies. The re-establishment of the Paleontological Society of the Philippines provides opportunities for paleontologists and enthusiasts to collaborate and advance palaeontological research in the country. The increasing effort to generate new knowledge by describing marine fossils in the Philippines will lead to a better understanding of the country's unique cultural heritage and natural history.



## FOSSIL OTOLITHS REVEAL THE TROPICAL FISH COMMUNITY IN THE PRESENT-TEMPERATE CENTRAL JAPAN DURING THE LAST INTERGLACIAL PERIOD

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### Keywords

Global Climate Warming, Late Pleistocene, MIS 5e, Palaeoichthyology, Teleosts



Present-day marine biodiversity hotspot of Japan has been formed through complex geological events during the Neogene-Quaternary. Among such events, the glacial-interglacial cycles had a major effect on marine biota, including fishes. For example, global climate warming has been observed to cause the expansion of tropical marine fishes and their communities to higher latitude areas of Japan. Therefore, records of warmer-than-present periods, such as the Marine Isotope Stage (MIS) 5e, draw particular interest as they may aid scientists to predict how marine fish communities could change in the future. Well-preserved body fossils of fishes allow us to approach the detailed marine palaeoecology, but the localities yielding such material are limited in Japan. Therefore, fish fossil records during such warming periods are less clear. Here, we aim to reconstruct local fish fauna during the MIS 5e by describing fossil otoliths from two localities in central Japan belonging to the Otsu Sand and Mud Member of the Yokosuka Formation. A total of 544 otoliths were analysed, revealing the presence of at least 35 taxa. The fish assemblages reflect a mixture of coastal to oceanic epi-mesopelagic species. In addition, the remarkable occurrences of two present-day tropical species demonstrate a once thriving tropical fish fauna in the higher latitude central Japan during the warmer-than-present last interglacial period.



## UNDERSTANDING THE DIVERSITY OF MOLLUSCA FOSSILS IN THE WEST PACIFIC: A CASE STUDY OF TROPICAL BIVALVIAN ASSEMBLAGE FROM THE SZEKOU FORMATION, SOUTHERN TAIWAN

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### Keywords

Bivalvia, Veneridae, Gastropoda, Scaphopoda, Neogene, biodiversity hotspot

Molluscan fossil fauna of Taiwan was actively studied in the second part of the 20<sup>th</sup> century. Basic works provided a detailed view on the species composition from different formations and provided essential paleoecological interpretations. However, there is still a lack of complete spatiotemporal understanding of the role of molluscan assemblages. Taiwan is regarded as the northern limit of the West Pacific marine biodiversity hotspot, which has been formed since the early Neogene. The fossil molluscan fauna is rich in species number and represents an interesting combination that can be traced in a north-south direction. However, a comprehensive study is needed to evaluate the whole fauna and its connection to other adjacent localities within the hotspot, which would shed new light on the emergence of the modern condition. In this study, we collected new materials from the Szekou Formation in southern Taiwan, targeting three conchiferan classes: Bivalvia, Gastropoda, and Scaphopoda. We present here the achievements of the taxonomic work.





## NEOGENE PLANKTONIC FORAMINIFERA AND CALCAREOUS NANNOFOSSIL STUDIES: BIOSTRATIGRAPHICAL FINDINGS OF SIBUTI FORMATION (BEKENU-NIAH ROAD) IN SARAWAK, MALAYSIA

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### Keywords

Neogene, Bekenu, Middle Miocene, Nannofossil, Sibuti



The Sibuti Formation in the Bekenu area in Northern Borneo is known to be rich in fossils. So far, the fossils retrieved from this area are corals, decapods, echinoids, fish remains, few foraminifera, molluscs and some pollens and spores. Although there have been diverse fossil findings, published records only concentrated on the description of macrofossils. In this study, therefore, microfossils are reported from the Sibuti Formation, particularly on planktonic foraminifera and calcareous nannofossils obtained from one of the exposed sites, the Bekenu-Niah Road outcrop. Here, the documentation of microfossils was done through the Scanning Electron microscopy, after which biostratigraphical analysis was conducted. The results show that the planktonic foraminifera and nannofossils retrieved are abundant and diverse. However, most of the specimens display calcite overgrowth and abraded wall surfaces. Planktonic foraminifera species identified include *Globigerinella obesa*, *Globigerinoides subquadratus*, *Globoturborotalita woodi* and *Trilobatus trilobus*. Nannofossil taxa observed include *Umbilicosphaera jafari*, *Reticulofenestra haqii*, *Cyclicargolithus floridanus*, *Reticulofenestra minuta*, *Coccolithus* cf. *C. bownii*, *Pontosphaera* sp., and *Sphenolithus* sp. Our biostratigraphic study suggests an age of earliest Miocene to the Serravallian (Middle Miocene), based on the last occurrence (LO) of *G. subquadratus*. The data fits well with the ages determined by benthic foraminifera, pollen analysis and Sr-isotope data of the Sibuti Formation. Nannofossil data further constrained the age limit to ~12.5 Ma using the LO of *C. floridanus*. In conclusion, the age of Bekenu-Niah Road sediments can be assigned to Early to Middle Miocene (Aquitanean to late Serravallian age, ~12 - 23 Ma).



## A REVIEW OF THE PROBOSCIDEAN FOSSIL RECORD OF THE PHILIPPINES

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### Keywords

Philippines, Luzon, Panay, Mindanao, Proboscidea



The Philippines is situated offshore mainland southeast Asia along the western Pacific Ocean. Proboscidean fossils are known across the archipelago even though it has mostly remained isolated throughout its emergent history. Fossils have been unearthed in the Pleistocene deposits of the islands of Luzon, Panay, and Mindanao. Two proboscidean families are represented in the Philippines – Stegodontidae with *Stegodon* and Elephantidae with *Elephas* and *Palaeoloxodon*. Still, the taxonomy and stratigraphy of the proboscidean fossils from the Philippines remain unclear, with the holotypes insufficiently described and some reportedly missing. We begin with a review of the proboscidean fossil record of the Philippines from the late 19<sup>th</sup> Century to the early 2000s. *Stegodon* fossils comprise most of the proboscidean materials in the country, with several species mentioned in the literature, including *S. mindanensis*, *S. cf. mindanensis*, *S. cf. trigonocephalus*, *S. cf. sinensis* (= *S. cf. orientalis*), and *S. luzonensis*, aside from those still undesigned. Previously, at least two forms were thought to have existed in Luzon, a large-sized and a dwarfed *Stegodon*. However, a recent survey concluded that only one form was present: *S. luzonensis*. Similarly, several elephant species are also cited but generally refers to two forms, a large-sized form designated as *Elephas* sp., *Palaeoloxodon* sp., *Elephas* cf. *namadicus* and *Elephas namadicus*, and a pygmy endemic form named *E. beyeri*. We then reexamined the figures of the holotypes of *S. mindanensis*, *S. luzonensis*, and *E. beyeri* to explore additional characteristics that can aid in clarifying the taxonomy of the Philippine fossil proboscideans.



## FROM WHALE FALL TO ELEPHANT FALL: NEW TAPHONOMIC OBSERVATIONS FROM THE PENGHU FAUNA

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### Keywords

Taphonomy, Penghu Fauna, whale fall ecosystem, endolithic boring, Ice Age



The Penghu Fauna, also known as the Taiwan Land-Bridge Fauna, is a group of animal fossils that are recovered from the Penghu Channel and nearby seabeds. The fauna lived approximately 30,000-10,000 years ago. Among them, *Palaeoloxodon* sp., *Bubalus teihardi* are the majority. Such terrestrial animals abound on the present-day seabed in fragments, suggesting some form of transportation. The goal of this study is to reconstruct the process of fossil deposition using the ecosystem stages of whale fall as a mechanism. There are four stages in the whale fall ecosystem, with the whale carcass progressing through the mobile-scavenger stage, the enrichment-opportunities stage, the sulfophilic bacteria stage, and the reef stage. During the sulfophilic bacteria stage, endolithic boring is often found within whale bones. In the fourth stage, the whale bones serve only as a habitat, and this is known as the reef stage. After identifying the surface attachments of the fossils, it was found that there were fragments and residual attachments of oysters, tube worms, corals, and other organisms that use fossils as substrates. Fossil samples were selected and cut for examination of fresh sections in detail. Although features associated with the cut sections in each sample varied, no endolithic boring was found in any of them. It is believed that the condition of the fossils on the seabed corresponds to the reef stage of the whale fall ecosystem. In summary, the carcasses of the Penghu Fauna are more likely to have been deposited in a terrestrial environment rather than a marine environment. Subsequently, these fossil-bearing units are under seawater in the Taiwan Strait due to global eustatic rises.



## DEFORMED SPECIMENS OF *SCAPHECHINUS MIRABILIS* FROM TOUKOSHAN FORMATION, MIAOLI, TAIWAN

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### Keywords

Pleistocene fauna, Quaternary Geology, Clypeasteroida, Tectonic deformation

Since Penglai orogeny began around 6 Ma, major faults and folds have occurred in the Western Foothills of Taiwan. Previous research on conglomerates of the Toukoshan Formation has confirmed that the stress around tectonic landforms can be interpreted based on deformed pebbles. Similar deformed features can be observed on specimens of the fossil sand dollar *Scaphechinus mirabilis* in Xihu, Miaoli region. Among the 110 specimens examined, a total of 7 well-preserved samples were studied via Micro-CT, and 16 thin sections derived from 10 samples were made. Fractures on fossils are documented based on the three-dimensional rendering of X-ray images and thin sections under a polarized light microscope. We suppose that there are two origins of fractures on specimens of *S. mirabilis*. Fractures associated with taphonomic weak planes are caused by overburden pressure. Linear shear fractures and contact marks are caused by regional tectonic stress. Due to the lateral direction of maximum main stress, the appearance of some deformed specimens is similar to a monocline induced by a reverse fault.





## NEW FOSSIL BIRDS IN TAIWAN REVEAL NOVEL PLEISTOCENE MIGRATORY AVIFAUNA IN EAST ASIA

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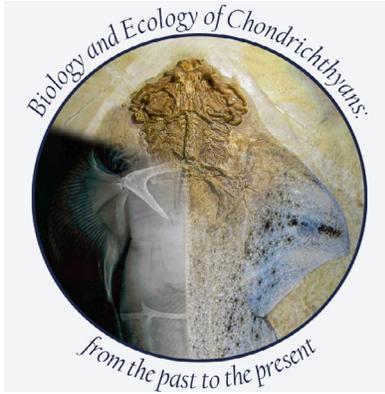
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### Keywords

Pleistocene, Taiwan, bird fossils, Gavia, East Asian-Australasian Flyway



The island of Taiwan, with its diverse microclimates and key position on the East Asian-Australasian Flyway, attracts numerous bird enthusiasts due to its diverse avian fauna. Nevertheless, due to the scarcity of fossil records, there is a significant knowledge gap between modern and ancient avian faunas in Taiwan. Currently, there is only a single described Pleistocene fossil attributed to Phasianidae. This study aims to address this gap by describing two new bird fossils, a left humerus and a left tibiotarsus, and discuss the ecological niches of the species that were present during that time. The fossils were collected from the Liuchungchi Formation (early Pleistocene, 1.90-1.35 Ma) in Niubu, Chiayi, southwestern Taiwan, which was a neritic zone at that time. The fossils are identified as Gaviidae (loons), with the humerus belonging to *Gavia adamsii* and the tibiotarsus to *G. stellata*. Gaviidae species are migratory birds that primarily distribute in high- and middle latitudes of the Northern Hemisphere, and the known Pleistocene Gavia species in the northern West Pacific are restricted to Japan. In addition, these birds are extremely rare in modern Taiwan, with records scarce and most are limited to northern and northeastern Taiwan since the 1860s, indicating that the modern Gavia species only occasionally visit Taiwan. The *Gavia* fossils of Taiwan not only provide valuable bird evolutionary and paleobiogeographic information in the subtropical West Pacific, but may also imply a distinct avifauna in the region during the early Pleistocene.



Chondrichthyans, or cartilaginous fishes, are the sister group to all other living gnathostomes and are one of the most successful vertebrate groups in Earth's history. Currently, the class Chondrichthyes comprises two major groups, the Elasmobranchii (sharks and rays) and the Holocephali (chimaeras). Together they encompass over 400 million years of independent evolution and have survived all five mass and several minor extinction events. Throughout its long evolutionary history, this group has inhabited a wide range of marine and

freshwater environments and comprises many keystone taxa for ecosystem functioning and maintenance in modern marine ecosystems. Although most chondrichthyans are mesopredators, the few large and iconic apex predators like the white shark or megalodon have captured the imagination of humanity since ancient times. Unfortunately, this fascination, coupled with fear, misinformation, and the high economic value of chondrichthyan products, has led to a steep decline of chondrichthyan populations in the last decades and many species are threatened by extinction today.

This thematic session aims to create a space for presenting, sharing, and discussing recent advances in chondrichthyan research. This includes (but is not limited to) the early evolutionary history, such as events of the first appearance and dominance of holocephalans in the Devonian–Carboniferous (including the end-Devonian extinction event), the rise of modern groups of elasmobranchs in the Mesozoic (Jurassic–Cretaceous), extinction and recovery after the K/Pg boundary, and the evolution of chondrichthyans during the Cenozoic.

Discussion and the exchange of ideas are essential to understand the dynamics that have driven the evolution of this iconic group, especially times immediately before, during, and after extinction events are of special interest in the light of the current anthropogenically induced extinction event. We welcome any contributions that focus on chondrichthyans from all geological periods. Also work on recent taxa can be presented here, however, we strongly encourage topics with an evolutionary background.

# Biology and Ecology of Chondrichthyans: from the past to the present

## Organisers

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## Thematic Session



## TRACING THE TROPHIC ECOLOGY OF *OTODUS* LINEAGE USING THE CALCIUM RECORD OF THEIR TEETH: EAT WITH THE GIANTS

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### Keywords

Trophic level, Elasmobranchs, Calcium, *Otodus*

The development of trophic analysis based on the isotopic composition of oxygen, carbon or nitrogen has opened new alternatives to the study of feeding behaviors in terrestrial and marine vertebrates. The stable isotopes of calcium ( $^{44}\text{Ca}$ ,  $^{42}\text{Ca}$ ,  $^{40}\text{Ca}$ ) measured in the enamel of vertebrate teeth has been correlated to their trophic level. It is estimated that calcium isotope fractionation between the food source and the predator is reflected along the food chain by a decrease in  $\delta^{44/42}\text{Ca}$  values with increasing trophic position, thus allowing the discrimination of trophic ranks, ranging from primary producers to apical predators, in the analyzed specimens. Elasmobranchs represent a very pertinent model for testing this method as they occupy all the consumers trophic levels in the marine food web and display a relatively abundant fossil record in marine deposits due to the continuous renewal of their teeth. This led to the abundance of available specimens for geochemical analysis in modern and paleontological collections. Here we present the interest and limits of this method, first performed on three modern species to assess the reliability of the method on elasmobranchs and then to species belonging to the megatooth lineage of *Otodus*, allowing to reconstruct changes in the trophic level of this emblematic Cenozoic shark lineage through time.





## HOW HAS SHARK FUNCTIONAL DIVERSITY CHANGED THROUGH GEOLOGICAL TIME?

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### Keywords

Functional diversity, Sharks, Cenozoic, Palaeoecology, Teeth



Modern sharks have a long evolutionary history (>250 million years), during which they have persisted through numerous environmental changes and played key ecological roles. Today, many shark species control prey populations via predation, with their decline negatively affecting food webs worldwide. Here, we assess how shark ecological functions have changed over time by quantifying changes in their functional diversity from the geological past to the present. Because ecological traits like body size and diet are hard to measure directly from their bodies, which are rarely preserved in the fossil record, we rely on their well-preserved and abundant teeth. Accordingly, we compiled a dataset of over 5,000 shark teeth from museum collections spanning the entire Cenozoic (66 Ma-present) and took different tooth measurements which have been demonstrated to be good proxies of ecological traits. Our results show that functional richness (FRic; volume of functional space; which represents the range or extent of ecological functions) – increased from the Palaeocene (~61 Ma) to the Eocene (~45 Ma), when it reached maximum levels (FRic = 51% of functional space). From then onwards, despite some fluctuations, functional richness generally declined to as low as 15% in the Pleistocene (~1.3 Ma). Although functional richness seemed to have recovered in the Recent, it remained 35% lower than its past peak. Taken together, our results demonstrate a general reduction in functional diversity from the past to the present, suggesting that some of the extent of shark ecological roles has been lost over time.



## ENVIRONMENTAL FORCING AND MAGNITUDE OF THE END-CRETACEOUS EXTINCTION AMONG CARTILAGINOUS AND BONY FISH AT A REGIONAL SCALE

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### Keywords

Elasmobranchs, Sharks, Mass Extinction, Diversity

The identification of mass-extinction events and the assessment of their impact on communities are key questions in palaeontology. In order to understand these catastrophic events on sharks and fish communities, it is necessary to combine reliable geological, paleontological and sedimentological data. Although the interpretation of depositional environments is important, the assessment of further proxies such as dissolved oxygen and fluctuations in bathymetry are useful to reveal the habitability before and immediately after an ecological crisis. However, interpretations of changes in marine vertebrate diversity and frequency in fossil remains across an investigated section are often hampered by limits on the available environmental data, or by sampling methods. These limitations can be reduced when combining extensive bulk sampling, taxonomical expertise and interpretations of ecological and environmental data. Here, we present new data from the last severe mass extinction event at the Cretaceous – Paleogene (K/Pg) boundary, 66 Ma. The newly recovered fossil material derives from 4.100 kg of sediment sampled from two localities preserving the K/Pg boundary in Austria and comprises over 6.000 ichthyoliths. Although both localities represent different environmental settings, the ichthyolith abundance of both studied sections indicate that sharks were less affected by the K/Pg mass extinction event than bony fish, which is in contrast to previous studies dealing with smaller sample sizes. This comprehensive study provides new insights on the magnitude of extinction of sharks and bony fish triggered by this well-known ecological disaster and contributes significantly to our understanding of this crucial period for marine biodiversity.





## NEOSELACHIAN DIVERSITY THROUGH DEEP TIME

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### Keywords

Chondrichthyes, Artificial Intelligence, Richness, Neural Network, Deep Learning



Modern sharks, rays, and skates (Neoselachii) have a long evolutionary history that started in the Early Triassic (~250 Ma). Different studies have shown that neoselachians reached their maximum diversity in the late Late Cretaceous (~72 Ma), sharply declined during the K-Pg (66 Ma), and maintained relatively stable diversity throughout the Neogene. However, our current knowledge of neoselachian diversity is likely to be biased by their inherently incomplete and patchy fossil record. Here, based on a novel deep learning approach of Artificial Intelligence and an unprecedented dataset of over 30,000 occurrences spanning the last 145 myr, we re-assess neoselachian diversity through time while accounting for Signor-Lipps, sampling, and spatiotemporal biases. In line with previous works, we found an increase in neoselachian diversity throughout the Cretaceous, culminating with a 52% increase in species richness during the Santonian (86 – 84 Ma), followed by the loss of 41% of species around the K-Pg (~66 Ma). However, unlike previous assessments, we found a second peak in diversity from the early Paleocene to the early Eocene (62 – 48 Ma), with a 62% increase in species richness. This recovery was followed by a near-continuous decline from then onwards, only temporarily interrupted by an 11% increase in the Middle Miocene (16 – 12 Ma). Overall, the decline resulted in the loss of over 50% of species in the last ~12 myr. Our approach revealed hitherto unrecognized patterns in the neoselachian past, suggesting we inherited an already depleted diversity, a third of which is at risk for extinction today.



## LABIAL CARTILAGES IN SHARKS – VARIETIES AND FUNCTIONS

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### Keywords

Labial Cartilages, Feeding Strategy, Anatomy, Morphology



Labial cartilages (LCs) are paired cartilaginous elements located on the labial sides of the jaws of sharks, skates, and rays. They are embedded in the muscle tissue and are considered to influence the ability to create suction during the feeding process. In sharks they are as diverse as the used feeding techniques and differ between species in number, size, shape, and position, displaying the large continuum of feeding strategies from pure ram/biting to pure suction and all variations in between. This allows for establishing parameters for inferring the feeding and hunting behaviors of these ecologically important fishes. Here we present a study of LCs based on more than 100 extant shark species comprising all known living families. Accordingly, sharks without LCs or having only small remnants are ram feeders or use pure biting, without or with only minor suction. They mainly occupy higher trophic levels (tertiary, quaternary consumers according to stomach content). Suction feeding sharks have higher numbers (up to five pairs) of well-developed LCs and occupy slightly lower trophic levels (mainly secondary consumers according to stomach content). Species with unique feeding strategies (like the cookie cutter shark, *I. brasiliensis*, who is an ectoparasite) display special shapes of LCs and generalist species display an intermediate condition of LCs. A literature review was used to determine different feeding strategies and compare them to the LCs present in the described species. The mean number of LCs within sharks is three. We propose a dichotomous key to classify the single LCs to a certain morphotype and propose combinations of morphotypes that represent the extent to which suction is used in the feeding process. The drawn conclusions can be used to shine a light on the feeding strategies of both extant sharks with unknown feeding strategies and extinct sharks.



## NEOSELACHIAN DIVERSIFICATION DYNAMICS AND AGE-DEPENDENT EXTINCTION

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### Keywords

Neoselachii, Extinction Mechanisms, Age Dependent Extinction, Diversification Dynamics



Neoselachians — modern sharks, rays, skates, and their extinct relatives — have an abundant fossil record and long evolutionary history. Previous studies suggest that after an extinction during the K/Pg crisis (~66 Ma), neoselachians have not suffered any other major global extinction events, except now, when human pressures are driving at least one third of their diversity to extinction. However, quantifying extinctions, and the factors associated with it, can be difficult given the inherent biases of the fossil record. Here, we compiled an unprecedented global dataset of neoselachian occurrences to assess their mechanisms of extinction over the last 145 myr. To do so, we use a Bayesian framework that accounts for sampling and preservation biases and that allows us to test for age-dependent extinction. Our results identify at least three hitherto unknown global extinction events in the Late Cretaceous (73.2 – 71.8 Ma), the Eocene-Oligocene (37.8 – 32.9 Ma), and from Pliocene onwards (5.3 Ma - Recent). Speciation was found to increase around times of elevated extinction suggesting high turnover, except throughout the Neogene and Quaternary, when it remained constant. We further found extinction rates to be persistently higher in young species. Our results advance our understanding of neoselachian evolutionary history, revealing that they have faced more extinctions than previously thought, with the last 13 myr standing out as a period of prolonged negative diversification. Importantly, regardless of the timing and intensity of events, extinction probability showed a decrease with taxon age, with great potential to inform conservation on the intrinsic traits associated with extinction risk.



## EARLY TRIASSIC CHONDRICHTHYANS FROM THE ZUODENG SECTION, GUANGXI PROVINCE, SOUTH CHINA: PALAEOBIOLOGICAL AND PALAEOBIOGEOGRAPHICAL IMPLICATION

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### Keywords

Elasmobranchs, Palaeobiodiversity, Palaeobiogeography, Tethys, China

Early Triassic chondrichthyans from China have been insufficiently studied up to date. Here we present a taxonomic study of a diverse chondrichthyan fauna from the Luolou Formation at the Zuodeng section in Guangxi Province, South China. Nine elasmobranch taxa are recognized, comprising two hybodonts (*Omanoselache halli* and *Hybodus* sp.), three neoselachians (*Safrodus tozeri*, *Polyfaciodus pandus* and *Synechodus* aff. *triangulus*), and four euselachians of uncertain affinities (*Favusodus orientalis*, Euselachii gen. et sp. indet., '*Hybodus*' *zuodengensis* and '*Hybodus*' *yohi*). A statistical analysis shows that the shark palaeocommunity had a high diversity and evenness, and a low dominance, indicating that the archipelagic Nanpanjiang Basin probably allowed the thriving of euselachian sharks. Their diverse morphologies indicate that the fauna demonstrated adaptations for a wide range of feeding strategies, including grasping-crushing, grasping-swallowing and sharp-grasping. Palaeobiogeographically, trans-Tethyan taxa reveal a shark dispersion path between the western Neo-Tethys (Oman) and eastern Palaeo-Tethys (Zuodeng) during the Early Triassic.





## ALTERATION OF Sr ISOTOPE COMPOSITION OF PLIOCENE SHARK TEETH ATTESTING PLEISTOCENE TRANSGRESSION IN MEXICO

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### Keywords

Chondrichthyes, Geochemistry, Sr-isotopes, Sea level, Glaciation



Strontium isotope composition represents a useful geochronological tool in paleontological samples from marine environments. Their  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios, inherited from seawater, remain almost unaltered in subsequent events and are preserved in biogenic minerals during their precipitation. This study was performed on shark teeth belonging to the species *Carcharias cuspidata*, *Carcharhinus leucas*, *C. falciformis*, *C. brachyurus*, *Galeocerdo cuvier*, *Negaprion brevirostris*, and *Rhizoprionodon* sp. (Early Pliocene, Piazencian age), all of them collected in Punta Maldonado Formation (Guerrero, México). The  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio analyses were performed in phosphates from the enameloid part of the teeth in the Unidad de Geocronología from the Universidad Complutense de Madrid.  $^{87}\text{Sr}/^{86}\text{Sr}$  values obtained (0.709117-0.709176) are not in line with the biostratigraphic age determined by Foraminifera and Ostracoda as we would otherwise expect values in the range of 0.709020. This younger age obtained by the geochemical analysis is interpreted as an alteration occurring in the presence of Pleistocene seawater that infiltrated the 5.3-3.6 My old sediments. This was caused by an homogenization event in the Sr isotope composition, where phosphates reached a new isotopic equilibrium, based on the interchange of the seawater during a glacial period. Results here presented agree with a transgression event during the Early-Middle Pleistocene Transition. This hypothesis is supported by comparable Sr isotope analysis performed at the University of Arizona in carbonates of mollusk (bivalve and gastropod) shells from the same locality.



## SHARK DIVERSITY FROM THE PLIOCENE OF THE PACIFIC COAST OF SOUTHERN MEXICO

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### Keywords

Fossil, Chondrichthyes, teeth, Pliocene, Fishes



The fossiliferous marine Pliocene (Piacenzian) outcrops of the Punta Maldonado Formation, at Costa Chica de Guerrero Mexico, contain a diversity of fossil fishes, including microscopic bony fish vertebrae and otoliths, and macroscopically the most conspicuous fish remains are the shark teeth. The latter are the target of the present study. A total of 53 shark teeth were found isolated and ex situ in the frame of many field trips performed in the years 2018, 2019 and 2022. The teeth were taxonomically identified based on their morphology. Identifications were corroborated by comparing the fossil samples with modern dentitions stored in the Mexican National Collection of Paleontology. To our knowledge, the present study is the first to investigate Pliocene chondrichthyans from the Pacific of southern Mexico. Here, we report the presence of six genera and seven species corresponding to *Carcharias cuspidata*, *Carcharhinus leucas*, *Carcharhinus falciformis*, *Carcharhinus brachyurus*, *Galeocerdo cuvier*, *Negaprion brevirostris*, and *Rhizoprionodon* sp. This fossil association consists mainly of widely distributed, largely intertropical extant species, except for the extinct *C. cuspidata*. Our finds support previous palaeoenvironmental reconstruction of the Punta Maldonado Formation as a warm infralittoral setting occasionally affected by upwelling conditions.



## CLIMATE CHANGE AND THE EVOLUTION OF NESELACHIAN SHARKS

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### Keywords

Ecology, Elasmobranchs, Pectoral Fins, Temperature



Neoselachian sharks are among the oldest yet most successful vertebrate clades. They occupy nearly every part of the marine ecosystem and are ecologically important predators. However, what drove the ecological diversification within this clade, as well as the timing of such changes, remain poorly understood. Given their function in locomotion, the size and shape of pectoral fins may explain the success of neoselachian sharks. We examined the evolution of pectoral fins in 490 neoselachian species in relation with their preferred habitat zone along the benthic-pelagic axis. Additionally, we examined numerous preserved fossil specimens for comparison. Our phylogenetic comparative methods show neoselachians were benthic in origin. In addition, we found that the Cretaceous was a critical time for neoselachian shark evolution as this is when the expansion into the pelagic zone occurred. This expansion coincided with a selective regime shift to higher pectoral fin aspect ratios. Evolutionary model fitting shows overwhelming evidence that pelagic sharks have high pectoral fin aspect ratios compared to other sharks. We also found high morphological differentiation within clades beginning in the early Late Cretaceous. Using estimates of swimming performance based on published muscle physiology experiments with benthic and pelagic sharks, we found that pelagic sharks likely swam faster than other sharks in warm Cretaceous waters. We hypothesize that temperature drove the increase in swim speeds which led to invasion of the pelagic zone and that individuals with higher aspect ratio pectoral fins had increased locomotory performance.



## Conservation Paleobiology

4th Palaeontological Virtual Congress

The global climate and biosphere are rapidly changing, with grave consequences for humans and nature. While humans

have affected the environment for millennia, systematic surveys of human impacts have only been conducted over the last few decades. This limits our ability to establish baselines and contextualize recent change because many recent observations are based on ecosystems that are already outside their range of natural variation. Therefore, to fully understand the adaptive capabilities and long-term resilience of stressor-exposed ecosystems, we must seek answers in the past.

Conservation paleobiology is an emerging field that applies methods and data from diverse disciplines, such as ecology, paleontology, geology, and conservation biology. By using the fossil record, conservation paleobiology provides insights into ecosystem dynamics and biotic responses to major environmental perturbations over millennia to millions of years. It enables the reconstruction of past ranges of natural variability as well as the evaluation of drivers and trajectories of long-term ecosystem change, with the purpose of guiding ecosystem conservation, restoration, and management.

We invite contributions from both researchers and practitioners on topics pertaining to paleontology and related fields, including (but not limited to) archaeology, anthropology, conservation, restoration ecology, wildlife management, and historical ecology. We encourage both near-time and deep-time perspectives on ecological and evolutionary processes during periods of environmental change (natural and anthropogenic) and potential biases affecting the fossil record. In addition, we welcome submissions on data-driven conservation efforts and collaborations with conservation practitioners.

We hope to gather exciting and thought-provoking contributions that will stimulate discussions among scientific disciplines, practitioners, stakeholders, and policy-makers around the most urgent questions in conservation paleobiology.

This session is supported by the Conservation Paleobiology Network (<https://conservationpaleorcn.org/>)



# Conservation Paleobiology: looking at the past, interpreting the present, planning for the future

## Organisers

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## Thematic Session



## FORBIDDEN ISLAND FOR BATS: UNTOLD STORY OF ANTHROPOGENIC EXTINCTION OF CAVE-DWELLING BATS ON A TROPICAL OCEANIC ISLAND

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### Keywords

Oceanic Island, Deforestation, Extirpation, Stable Carbon Isotope, Long Winged Bats



Geographic barriers and environmental filters yield species-poor communities with a high percentage of endemic taxa. In these insular settings, human colonization has increased extinction risks of native species via industrial activities and the introduction of invasive species. The Daito Islands in Okinawa, Japan have been physically isolated from continental landmasses since their emergence, and they harbor only one extant native mammal, which is the Daito fruit bat. Here, I present a case study using a multiproxy paleontological approach to reveal the cause of extinction of two other bat species from the islands. In the tropical caves of the islands, skeletal materials did not preserve sufficient bone collagen for direct radiocarbon dating. Alternatively, we examined previously reported guano deposit for indirect dating and analyzed stable carbon isotopes in bone apatite for detecting signals of  $C_4$  plants based on the historical knowledge that early human settlers quickly replaced the island's native  $C_3$  forests with sugarcane plantation from 1900 onward. Based on FT-IR, and XRD, the guano deposits were determined to be humic acid; however, its depositional condition suggests the maximum age of 4640 calBP for the bat fossils. The isotope analysis revealed  $C_4$  signals in various degrees, confirming that small populations of cave-dwelling bats remained after 1900. Our study suggests that these bats likely faced a continuously high mortality risk due to severe anthropogenic stresses on the heavily cultivated island, and that a paleontological approach can provide useful evidence regarding recent extirpation events not directly observed via zoological investigation.



## ECO-EVOLUTIONARY CONSEQUENCES OF EXPLOITATION IN THE ATLANTIC BLUEFIN TUNA: IMPLICATIONS FOR MANAGEMENT AND CONSERVATION

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### Keywords

Shifting Baselines, Marine Restoration, Marine Historical Ecology, Ancient Dna,  
Zooarchaeology



We evaluate anthropogenic impacts on the iconic Atlantic bluefin tuna (*Thunnus thynnus*; BFT), one of the longest and most intensely exploited marine fishes, with a tremendous cultural and economic importance. Using a long time series of archaeological and archived faunal remains (bones) dating back across two millennia ago, we apply morphological, isotopic and genomic techniques to perform the first studies on long-term BFT size and growth, diet and habitat use, demography and adaptation, and produce the first whole genome data on this species. Our findings suggest that exploitation had impacted BFT foraging behaviour by the ~16th century when coastal ecosystem degradation induced a pelagic shift in diet and habitat use. We reveal that BFT biomass began to decline much earlier than hitherto documented; that is by the 19th century, consistent with intensive tuna trap catches during this period and catch-at-size increasing. We find that BFT juvenile growth had increased by the early 1900s which may reflect an evolutionary response to size selective harvest. Furthermore, we observed that BFT foraging behaviours have been modified following overexploitation during the 20th century, which previously included a isotopically distinct, Black Sea niche. Finally, we show that despite biomass declining from centuries ago, BFT has retained genomic diversity. This provides confidence for its long-term recovery, suggesting that management plans can be ambitious with recovery targets. However, the loss of a Black Sea trophic niche, and potential for fisheries-induced evolution is concerning and requires consideration in policy.



## DID SEA LEVEL RISE CAUSE THE DISAPPEARANCE OF SOUTH CALIFORNIA'S MANGROVES DURING THE EARLY HOLOCENE?

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### Keywords

Mangrove Bivalves, Holocene Climatic Variation, Environmental Reconstruction, Human Subsistence



Global changes in climatic patterns throughout the Holocene have affected the relationship between ecosystems and human populations which inhabit them. With the objective of inferring the effect of rising sea level on mangrove habitats and their exploitation by humans, we carried out radiocarbon dating and ecological indexes of shells belonging to archaeological sites of Punta Faro del Marquez in Baja California's Pacific coast. Our results indicate the abundance of mangrove bivalves *Anadara tuberculosa* and *Anadara grandis* in the archaeological strata of the early Holocene, suggesting the importance of mangrove ecosystems for the subsistence of early coastal human communities. Subsequently, an abrupt absence of these species in the archaeological strata was identified circa 8000 BP extending to the present, suggesting the rapid disappearance of mangrove forests in the region. These results coincide with Mid-Holocene sea level rise, SST changes and fluctuating oceanographic conditions recorded for the Baja California Peninsula. Today mangrove forests of Baja California's Pacific coast are scarce, fragmented, and represent the northern latitudinal limit of such ecosystems in the Eastern Pacific. Therefore, our understanding of how these ecosystems have been historically affected by changes in climatic patterns, and as a result themselves affecting human communities, is imperative for mangrove forest conservation.



## CONSERVATION PALEOBIOLOGY IN PATOS LAGOON ESTUARY, BRAZIL: BASELINE CONDITIONS OF A BIVALVE GENUS

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### Keywords

Time-Averaging, Southern Brazil, Paleobiogeography, Radiocarbon Dating, Coastal Evolution



Since global environment is being altered by climate change and years of human impacts, biodiversity baselines and long-term data must be established for future species' conservation and management. For this reason, conservation paleobiology is a growing field with relevant tools needed to achieve these goals. The present study aims to understand the baseline and the paleobiogeography of the bivalve *Mactra* Linnaeus, 1767 in the Patos Lagoon Estuary (southern Brazil) through time-averaging estimates. During the years 2018 and 2019, death assemblages were collected in different locations in the estuary. All *Mactra* sp. shells were separated and counted, 30 specimens (average length: 12.9 mm) were dated using carbonate accelerator mass spectrometry (0 cal yr BP = 1,950 AD). The 14C ages spanned between 1,921 and 40,485 cal yr BP (median: 2,690 cal yr BP) — five valves are older than 4,000 cal yr BP (37,902-40,485 cal yr BP), probably native of Pleistocene deposits nearby. The absence of *Mactra* sp. younger than 1,900 cal yr BP in these assemblages is likely evidence of a decline in the species production before the nearby city's settlement by Portuguese. On the other hand, this result could be age-related with the coastal evolution of the region: between 3 and 1.5 ka the progradation rate of the barrier increased and the sea level was continuously falling, moving the bivalves' favourable living area (poly-euhaline waters) seawards. This research highlights that the palaeobiological knowledge of how mollusks' distribution was affected by coastal processes can contribute for future conservation efforts.



## EFFECT OF HOLOCENE ENVIRONMENTAL CHANGES ON NORTHERN ADRIATIC POPULATIONS OF THE CLYPEASTEROID ECHINOID *ECHINOCYAMUS PUSILLUS*

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### Keywords

Echinoderm, Body Size, Conservation Paleobiology, Historical Ecology, Adriatic Sea

The impact of long-lasting human stressors on populations of marine benthic species is often difficult to assess due to paucity of long-term monitoring data. The youngest fossil record preserved in sediments cores and grab samples provides a unique historical archive, that enables tracing ecological responses to natural environmental changes and reconstructing the state of populations prior to the onset of anthropogenic impacts. However, most studies using these palaeoecological records focus on molluscs and little is known about the responses of other major components of marine ecosystems like echinoids. The infaunal clypeasteroid *Echinocyamus pusillus* can be used as model species for tracking long-term population dynamics due to its wide distribution, high abundance, and high preservation potential. Here, we examine changes in test size, density, and frequency of traces of drilling predation during the last ~11000 years in the shallow northern Adriatic Sea, where coastal marine habitats are under prolonged anthropogenic pressure. The sediment cores and grab samples taken from four stations, representing different benthic habitats, document environmental changes during the post-glacial transgression and the Holocene-Anthropocene transition, as indicated by shifts in molluscan assemblages and geochemical proxy records. However, preliminary results suggest that *E. pusillus* test size remained remarkably stable through time in all stations, despite pronounced spatial and temporal variability of abundance. We provide a fundamental baseline for evaluating changes in body size, abundance, and predatory interactions associated with recent intensification of human impacts on the Adriatic ecosystems, that can be compared with recent and fossil monitoring data from other areas.





## INCORPORATING FOSSIL DATA INTO CLIMATE CHANGE VULNERABILITY ASSESSMENTS

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### Keywords

Climate Change, Species Distribution Models, Fossil, Niche



Climate change represents one of the most concerning anthropogenic threats to biodiversity and ecosystems. Often, the incompleteness of occurrence data used to forecast climate change impact on biodiversity may hamper the reliability of these predictions. In our research, we aim at evaluating whether the inclusion of paleontological records into Species Distribution Models (SDMs) significantly increases the width of sampled climate niche by providing information on species-climate relationships from the past. We collected current and fossil occurrence data for 38 mammal species, along with a set of climate variables covering the last 800 kya and rasterized at ~50 km spatial resolution. In addition, we retrieved 2100 climate variables according to two climate change scenarios (RCP4.5 and RCP8.5). Starting from these data, we calibrated SDMs relying on living occurrences alone ("Only-living" SDMs) and pooling living and fossil occurrences ("Full" SDMs). Models were projected over current time and 2100 under RCP4.5 and RCP8.5 scenarios. Both Only-living and Full SDMs achieved good predictive performances (Only living SDMs mean AUC=0.817; Full SDMs mean AUC=0.820). In addition, we showed that the increase in climate niche width granted by the inclusion of fossil data is significantly correlated with a reduction in range net change predicted by "Full" SDMs with respect of "Only-living" ones ( $r=0.10$ ,  $p < 0.01$ ). Our results provide evidence that including fossil data into SDMs allows a more comprehensive sampling of the climatic niche and leads to overall milder climate change effects predicted on biodiversity.



## WHAT IS CONSERVATION PALEOBIOLOGY? TRACKING 20 YEARS OF RESEARCH AND DEVELOPMENT

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### Keywords

Cross-Disciplinarity, Geohistorical Data, Conservation Science, Survey, Systematic Literature Search

Conservation paleobiology has coalesced over the last two decades since its coining, united by the goal of applying geohistorical records to inform the conservation, management, and restoration of biodiversity and ecosystem services. Yet, the field is still attempting to form an identity distinct from its academic roots. Here, we ask a deceptively simple question: What is conservation paleobiology? To track its development as a field, we synthesize complementary perspectives from a survey of the scientific community that is familiar with conservation paleobiology and a systematic literature review of publications that use the term. We present an overview of conservation paleobiology's research scope and compare survey participants' perceptions of what it is and what it should be as a field. We find that conservation paleobiologists use a variety of geohistorical data in their work, although research is typified by near-time records of marine molluscs and terrestrial mammals collected over local to regional spatial scales. Survey participants indicated that conservation paleobiology can incorporate information from a wide range of disciplines spanning conservation biology, ecology, historical ecology, paleontology, and archaeology. Finally, we show that conservation paleobiologists have yet to reach a consensus on how applied the field should be in practice. Many thought the field should be more applied, but most do not engage with conservation practice. Reflecting on how conservation paleobiology has developed over the last two decades, we discuss opportunities to promote community cohesion, strengthen collaborations within conservation science, and align training priorities with the field's identity as it crystallizes.





## THE STEPPE-TUNDRA BIOME: WHAT'S LEFT FROM THE MAMMOTH STEPPE

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### Keywords

Heinrich Walter, Pleistocene, Paleobiology, Paleoclimate, Gis



The climatic conditions during the Last Glacial Maximum (LGM) favored the presence of a cold and dry climate known as the steppe-tundra or mammoth steppe. This biome was broad in extent during the Pleistocene, and spanned from the Iberian Peninsula to North America, through the Bering Strait, and from the highest arctic latitudes to North China. The fossil record shows that it hosted the woolly mammoth and other herbivores in the Pleistocene, including reindeer, steppe bison and musk ox. Many researchers have studied this biome throughout the years and found a few modern analogs of the Pleistocene steppe-tundra. Identifying and studying these analogue regions could help us to better understand these ecosystems during the LGM and to protect and preserve these habitats today as potential areas for Pleistocene rewilding. We developed a R function to identify the current global biomes according to Walter's classification. This author divided terrestrial biomes according to climatic data, identifying nine global biomes. To accomplish our goal, we used precipitation and temperature data from the WorldClim database v.2.1, corresponding to the 1961-1989 timespan, before the effects of current global warming became prominent in the climatic record. The biomes global distribution, obtained through GIS methods implemented in R language, included a few regions of the steppe biome within the modern tundra of North America and Eurasia. We delved into these results to analyze whether such isolated steppe spots might represent actual steppe-tundra biome analogues and how this is important for conservation, paleontological studies, and biodiversity.



## THE HISTORY OF THE EARTH THROUGH SCIENTIFIC COMMUNICATION AMONG PEERS. A DIDACTIC PROPOSAL

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### Keywords

Scientific understanding, Upper Secondary Education, Sustainability, History of the Earth



Although knowledge of the scientific method is a key part of scientific literacy, the promotion of curiosity and the development of critical thinking and problem-solving abilities are critical features than often get overlooked. To promote these aptitudes among the student body, we developed a didactic proposal focusing on public speaking as a tool for didactics of the experimental sciences. Our initiative was carried out with 132 students in the 3rd course of Secondary School Education (14-15 years old), who prepared and shared communications on the topics of Earth's history and Sustainable Development Goals (SDG). Each geological era was paired up with a Sustainable Development Goal to which it is thematically related. For instance, the importance of preserving biodiversity (SDG 15) and the Precambrian, taking action to mitigate the effects of climate change (SDG 13) and the Mesozoic, or building sustainable and resilient communities (SDG 11) with the Cenozoic. Each group of students conducted a literature review on their assigned geological period. For example, during the Carboniferous, the largest oil reserves were generated due to the large amount of vegetation. The students pondered on the millions of years needed for the formation of this hydrocarbon, and the speed with which it is consumed today. This led them to reflect on alternative fuels for vehicles or more sustainable ways of getting around. Special attention was paid to the internalization of the phases of the scientific method by the students, with a specific interest in the communication and dissemination of results, given its essential role in the advancement of science. To this end, a scientific conference with oral poster presentations was organized so that the students could share their results. To assess the extent to which the proposal was satisfactory, a questionnaire was carried out before and after the experience to measure the evolution of the students' knowledge and motivation for Earth history. This is an ongoing investigation. Details of the analysis of the results will be provided in the extended communication. We are optimistic about achieving positive outcomes, as the students will develop a more comprehensive understanding of knowledge, forging connections between geology and environmental issues.



## CLIMATE CHANGE AND NICHE EVOLUTION IN QUATERNARY MAMMALS

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### Keywords

Climatic Niche Evolution, phylo.niche.shift, RRphylo, Ungulates, Quaternary



The Quaternary period witnessed profound and often rapid climatic changes characterized by the alternation of cold, glacial periods to warmer interglacials that affect mammalian megafauna diversity and distribution. Different species responded differently to the challenge posed by the swinging climates, with some clades taking advantage and others being hit by the mutable conditions. Usually, more tolerant, less specialized species are able to adjust and benefit from reduced competitive pressure caused by environmental changes (*i.e.*, the red deer, wolf). On the opposite, specialized species (*i.e.*, sabertooth cats, woolly mammoth) are more affected by the change. Understanding how species reactions unfolded and what made them different from one another is key to predicting mammalian responses to current climate change. Yet, explicit measurements of the realized niche are needed to depict its temporal evolution and its climate-related changes. Here, we apply the recently-developed phylo.niche.shift algorithm to assess the rate of niche evolution in Quaternary large mammals from Eurasia. This method integrates phylogenetic comparative methods (RRphylo) to climatic niche parameters to identify clade-wise shifts in rates of niche evolution and niche drifts (*i.e.*, a change in the position of the climatic niche of the clade). As expected, we found generalist species to have larger and less stable niches.



## WHERE THEY ARE AND WHERE THEY'VE BEEN: MODELLING ELD'S DEER DISTRIBUTION FROM THE PLEISTOCENE

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### Keywords

Eld's deer, Species distribution modelling, Conservation palaeobiology, Fossil data, Palaeodistribution

Eld's deer (*Rucervus eldii*, McClelland 1842) is a cervid species native to Southeast Asia. Historically, they were present across 7 countries, including India, Myanmar, Thailand, Cambodia, Laos, Vietnam, and China (Hainan Island). Three formally recognised and one putative subspecies exist in reduced and fragmented populations. However, as a species, their population numbers are declining, and they are classified as Endangered by the IUCN (2014). Due to their fragmentation, current population numbers are estimates, and their habitats vary between populations, making unified conservation practices challenging for the species, and indicating a potentially wider, unexploited, realised niche. Species distribution models (SDMs) match georeferenced data points for species presence with contemporary environmental variables, allowing the forecasting of potential suitable habitat. Currently, Eld's deer presence has been noted from 17 sites across 6 countries, with absolute dates ranging from the Late Pleistocene to Late Holocene. In addition to presence data, the palaeoenvironmental context of the site localities, including co-occurring mammal taxa, vegetation cover, and habitat reconstructions have also been collected from the literature. By incorporating palaeodistribution data into MaxEnt SDMs with contemporary ranges, projections of Eld's deer potential distributions in both the present and under future (2070) climate scenarios will be generated. By understanding Eld's deer palaeoecology, determinations of whether the species has suffered ecological niche truncation and range contraction can be obtained, to better understand their full realised niche potential, and to aid in conservation practices. In this presentation, results from preliminary analyses will be discussed, and confounding factors will be considered.





## CHANGES IN GROWTH, AGE STRUCTURE, AND HABITAT IN THE LARGE YELLOW CROAKER FROM THE PLEISTOCENE TO RECENT

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### Keywords

*Larimichthys crocea*, stable isotope, otolith, archaeological site, overfishing



Overfishing can lead to significant changes in the life history of fish, including alternations of habitat usage and growth rate. The large yellow croakers (*Larimichthys crocea*) in the Northwest Pacific have been severely exploited to the brink of ecological extinction for nearly half a century. Reconstructing the baseline of growth pattern and habitat use is crucial to biological conservation and fishery management. This study used the otoliths collected from the field of Nibu and Tainan Science Park archaeological museum and fishing port representing three different periods (modern, archaeological 300-5000 BP, fossil Early Pleistocene) that correspond to levels of human activities and environmental background condition. We determined the age of the fish by counting the annulus and verifying the determination with stable isotope ( $\delta^{18}O$ ). And the age classes of modern large yellow croaker are more younger (0.9) than archaeological site (2.8) and fossil (5.3). Our results indicate that the modern otoliths have a higher growth rate ( $k=2.65$ ) compare to the archaeological ( $k=0.44$ ) and fossil samples ( $k=0.41$ ). The average summer minimum oxygen isotope value of the modern otoliths is lighter (2.2‰) than that of the archaeological and fossil otoliths, both of which are lower than -3‰, reflecting a brackish water signature. This suggests that the large yellow croakers may have inhabited estuaries or lagoons during the archaeological and fossil periods, while the modern ones complete their life cycle in the oceanic environment. Our study shows that overfishing can act as a selective pressure, causing changes in increased growth rates and shifts in habitat use. Understanding the natural baseline of such endangered species is critical for effective conservation and management.



## GOING BACK FOR THE FUTURE: INCORPORATING PREHISTORIC FOSSIL RECORDS OF SAIGA ANTELOPE (*SAIGA TATARICA* LINNAEUS, 1776) INTO HABITAT SUITABILITY MODELS TO INFORM FUTURE CONSERVATION ACTIONS

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### Keywords

Habitat suitability, species distribution models, *Saiga tatarica*, Pleistocene fossils



Globally, biodiversity needs immediate and effective conservation action. Prioritising suitable areas for conservation requires detailed knowledge of species-environment relationships. However, many species have suffered human-induced range contraction and may no longer occupy the full breadth of environmental conditions they could inhabit. This is particularly problematic for habitat suitability models (HSMs), which relate georeferenced occurrence records with environment variables to predict probability of presence or habitat suitability. The outputs are used to inform conservation management decisions, such as identifying reintroduction sites and designing protected area networks. HSMs assume that a species' contemporary range reflects its full species-environment relationship and may consequently underestimate suitable habitat predictions, thereby misinforming and biasing conservation decisions. Incorporating historic (centuries-old) occurrence records partly reduces this bias, yet even these records are still subject to anthropogenic range modification. The inclusion of deeper-time Pleistocene fossil records into HSMs is an effective way to broaden understanding of species' ecological tolerances and environment relationships prior to extensive anthropogenic actions. Here, we used prehistoric fossil records of the critically endangered and evolutionary distinct saiga antelope (*Saiga tatarica* L., 1776) from the Late Pleistocene, alongside historic and modern occurrence records, to model suitable habitat under current and future (2070) climate projections. The results found an underestimation of predicted suitable saiga habitat using modern and historic records alone. The addition of prehistoric fossil records increased suitable saiga habitat by 780% and 1725%, under current and future climate projections respectively. Our results suggest the saiga is not a refugee species but is occupying only a portion of its environmental range, having suffered species-environment truncation. Overall, this study highlights the importance of incorporating prehistoric fossil records into HSMs, to reduce the effects of species-environment truncation and to better inform conservation management decisions.



## RESCUING THE RED DOG: USING THE PLEISTOCENE FOSSIL RECORD OF THE DHOLE (*CUON ALPINUS* PALLAS, 1811) TO INFORM MODERN CONSERVATION INITIATIVES

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### Keywords

Species distribution model, conservation palaeobiology, Pleistocene fossils, *Cuon alpinus*, Dhole



The dhole (*Cuon alpinus* Pallas, 1811) is a medium-sized evolutionarily distinct canid, currently distributed only in Southeast Asia, after experiencing drastic range contraction and eventual extirpation from North America and Europe after the Late Pleistocene. Despite being threatened by prey depletion, habitat destruction and competition, little is known about the dhole's distribution and ecology. Dhole-specific conservation strategies are minimal, if not entirely absent in most range countries. Populations reside mainly in areas designated as protected for other charismatic species, such as tigers and elephants, but their adequacy for dhole conservation is undetermined. Species distribution models (SDMs) that relate georeferenced occurrence records to environmental variables could be used to identify suitable dhole conservation strategies. However, modern dhole distribution data is sparse and heavily influenced by human interactions, which could introduce bias into model projections and misinform conservation actions. Incorporating the dhole's Pleistocene fossil record into models could potentially reduce the effects of limited contemporary ecological data, by including palaeoclimate, palaeoenvironmental and competitive forcing factors over a longer time period. Fossil records can offer deep time insights into the responses to past environmental change of both individual species and ecological communities, as well as broadening understanding of species' full environment relationships prior to extensive human activity.



## BIVALVE RESPONSE TO PLIO-PLEISTOCENE CLIMATE CHANGE IN THE MEDITERRANEAN SEA

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### Keywords

Species Richness, Extinction Risk, Species Turnover, Regime Shift



The Mediterranean Sea is recognized as a hotspot of marine biodiversity. Such extraordinary diversity is currently threatened by global warming that may impact marine communities and trophic relationships among organisms at different depths. To better predict to what degree marine species are vulnerable to recent and future climate change it is necessary to investigate how species reacted to environmental disturbances in the geological past. In this study, we analyzed how species richness changed during the Plio-Pleistocene, a period characterized by multiple waves of bivalve extinctions, using the fossil record of more than 400 Mediterranean bivalve species belonging to 68 families. After assembling a species level dataset, we measured changes in species richness across different palaeoenvironments and for different combination of tiering and feeding categories in order to verify if specific environmental conditions and different lifestyles selectively increased ecological resilience to climate change. Ecosystem response was assessed in terms of species richness, species turnover, niche breadth, geographical range size, and species abundance. A significant loss of biodiversity in the Mediterranean area was registered after 3 million years ago, especially in shallow water environments, consistent with the onset of cooler climatic conditions and the disaggregation of carbonate ramp habitats. In addition, our results suggest that suspension feeders lost the highest species richness, whereas deposit feeders were much more resilient to the environmental change. Although bivalve richness gradually decreased towards the Pleistocene, this period had the higher proportion of species appearances. We hypothesize that this is due to the onset of cooler climatic regime and the introduction of boreal guests.



## HISTORY OF GEOGRAPHIC RANGE AN INFORMATIVE PREDICTOR OF EXTINCTION RISK ACROSS MULTIPLE MICROPLANKTON TAXA

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### Keywords

Conservation Paleobiology, Geographic Range, Extinction



While geographic range size is often acknowledged as an important factor in determining a species' extinction risk, the temporal trajectory of geographic range is not always considered. Four major microplankton groups — foraminifera, calcareous nannofossils, radiolarians, and diatoms — were examined with respect to their geographic range and the temporal trajectory of their geographic range, and how those terms relate to extinction probability. Logistic modeling was used to explore these relationships for each extinct species in the microplankton data sets, which ranged from over 100,000 to nearly 250,000 occurrences each and were sourced from the Neptune Sandbox Berlin database. Occurrences ranged from the late Jurassic to the present. For each data set, model coefficient ratios and the proportion of total deviance reduction attributable to each term were calculated. Our findings suggest that change in geographic occupancy through time can account for up to 37% of gross extinction risk. Additionally, the change in geographic occupancy through time is on average 4.6 times more informative in siliceous microplankton than in calcareous microplankton. We suggest that the more opportunistic life mode of siliceous microplankton is responsible for this pattern. The fact that geographic occupancy trajectory can be used as an informative predictor of extinction risk demonstrates the benefit of incorporating paleontological data into modern conservation efforts, providing further affirmation to the relatively new field known as “conservation paleobiology.”



## WHERE THE WILD THINGS WERE: AN ONLINE ATLAS OF CHARISMATIC ANIMAL LOSSES FROM THE PLEISTOCENE TO TODAY

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### Keywords

Pleistocene, Megafauna, Conservation Paleobiology, Biogeography, Outreach



Since the Pleistocene, over half of all large animals have become extinct. These losses have transcended prehistoric, recent, and modern times — accelerating respectively. To highlight these losses as a whole, we created a pilot of Where the Wild Things Were: an interactive web atlas of charismatic animal losses from the Pleistocene to today. Through this, we aim to: 1) Create a unique resource that instills a sense of awe and place in the public via connections between Quaternary vertebrate paleontology and the present, and 2) Use that sense of awe and place to promote paleontology literacy and conservation engagement (*e.g.*, inspiring Earth science and conservation careers) through the link between Quaternary animal losses and the world today. This pilot version includes ArcGIS StoryMap entries on charismatic megafauna, including woolly mammoths (*Mammuthus primigenius*), Columbian mammoths (*M. columbi*), jaguars (*Panthera onca*), American lions (*P. atrox*), and saber-toothed cats (*Smilodon fatalis*) of the United States. We include information about these species' natural histories, historic ranges, extinction hypotheses, and connections to modern analogs using maps we created with data from palontological and neontological databases, along with Creative-Commons-licensed images, videos, and hyperlinks to peer-reviewed publications plus relevant conservation organizations. By evoking connections to these animal losses through a sense of place, we hope to intrigue, evoke, and inspire users for effective conservation action.



## USING LATE QUATERNARY CAVE DEPOSITS FROM NORTHEASTERN QUEENSLAND, AUSTRALIA TO ESTABLISH BIODIVERSITY BASELINES FOR CONSERVATION

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### Keywords

Quaternary, Fossils, Baselines, Biodiversity, Conservation



Examining Australia's late Quaternary fossils from limestone caves in the Broken River region (northeastern Queensland) can be valuable in documenting local vertebrate palaeocommunities and understanding their long-term environmental responses. This is important for modern biodiversity conservation that requires predicting future changes, given trends in current global climate, habitat loss and other anthropogenic impacts. On-going taxonomic analysis shows the presence of new but extinct species of hopping mouse (*Notomys* sp.) in older (lithified) deposits and rock rat (*Zyzomys* sp.) from older and younger (surface) deposits, alongside previously described globally extinct taxa, indicating that extinctions in late Quaternary Australia may be worse than previously realised. The younger, pre-European surface deposits additionally reveal fossils of several locally extirpated taxa like Cape York Bandicoot (*Isoodon peninsulae*) and Swamp Rat (*Rattus lutreolus*). Their presence as fossils, compared with their extant distribution, demonstrates considerable range contractions since the deposits accumulated, suggesting their extant populations may be depauperate. Fossils of Plains Mouse (*Pseudomys australis*) and Forrest's Mouse (*Leggadina forresti*) suggest expanded arid zones in the past due to their current distribution/habitats in central Australia, while fossils of Common Ringtail Possum (*Pseudocheirus peregrinus*) indicate the presence of temperate-tropical forested habitats locally; their absence in the area today could either be a result of habitat loss and/or progressive aridification — or a dearth of adequate ecological surveys. Investigating these cave deposits therefore highlights the importance of shifting existing faunal baselines and the need for detailed modern surveys for understanding the response of Broken River fauna to past and future changes.



## PALEOBIOLOGIC DATA AS A WINDOW TO THE FUTURE FOR CONSERVATION DECISION-MAKING

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### Keywords

Paleoecology, Conservation, Restoration, Pre-Disturbance, Trajectory of Change



The twentieth century saw significant increases in the rate of change of climate, sea level and the biosphere; yet resource managers are tasked with making decisions about conservation and restoration of ecosystems and biota under these rapidly changing conditions. Paleontologic data can provide these resource managers with a way to anticipate and plan for biotic responses to future conditions. To illustrate, the restoration of the Everglades ecosystem of south Florida, U.S.A., is focused on restoring more natural hydrologic conditions and reversing the negative impacts of canal construction in the 1950s and 60s. Restoration managers have targeted pre-disturbance conditions as their restoration goals. Molluscan assemblages from sediment cores collected in the estuaries indicate that salinity has been gradually increasing over the last few centuries to millennia, most likely due to sea level rise. Any attempt to return to the hydrologic conditions prior to canal construction will meet with failure, because it does not take the long-term trajectory of change in the ecosystem into consideration, nor does it account for all the anthropogenic changes that have occurred. Using paleontologic data over appropriate times scales can reveal natural trajectories (or cycles) of change in the physical (*e.g.*, salinity), biological (*e.g.*, abundance of a species), or chemical (*e.g.*, nutrient availability) components of an ecosystem. When these natural trends of an ecosystem are revealed through paleontologic data, resource managers can set anticipatory restoration and conservation targets — targets that get a system back to its natural trajectory of change at some point in the future.



The great significance of small mammals in fossil and extant communities is undeniable. Their functional roles in ecosystems as pollinators, dispersers, predators and preys, as well as ecosystem engineers are fundamental. They also constitute important biostratigraphic markers.

Their species richness, diversity and geographic distribution through the Cenozoic is intimately linked to the geologic history of the area where they inhabit.

In the last years, several advances in the study of small fossil mammals include the discovery of new fossiliferous outcrops, improvements on scanning and photographic techniques, morphometric and statistical analyses, and their integration on robust phylogenies.

Albeit their importance, research on small fossil mammals has different levels of development in different parts of the world. More investigations on these small treasures of biodiversity are necessary for a better understanding of their roles in past communities.

In this session, contributions concerning taxonomy, evolution, paleoecology, paleobiology, systematics, functional morphology and conservation of fossil small mammals are welcomed. We encourage contributions dealing with the best-known groups (as rodents) as well as lesser known groups (such as insectivores or bats).



# Small mammals: hidden treasures of biodiversity

Organisers

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## Thematic Session



## NEW SMALL MAMMAL SPECIES IDENTIFIED IN THE HISTORICAL SITE OF THE VALDEGOBA CAVE (BURGOS, SPAIN)

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### Keywords

Upper Pleistocene, Rodents, Micromammals, Biodiversity



The paleontological and archaeological site of the Valdegoba cave (Burgos, Spain), located in the Cantabrian Mountain Range, is an historical site characterized by the paleontological records and the remains of Neanderthal fossils and lithic industry. The systematic excavations began in 1987, and continued until 2006, with a total of six excavations campaigns, and the data obtained have been used in different papers about the Upper Pleistocene of the Iberian Peninsula. However, there have not been further additions, or studies, to the small mammal association since the first description of this site, in the year 1988. A total of 11 species of small mammals were previously identified, in 1988, that indicate cold (e.g., *Marmota* cf. *marmota* and *Chionomys nivalis*) and warm (e.g., *Hystrix* cf. *vinogradovi*) climate conditions. Through the study of the microfossils concentrates stored and subsequently sieve-washed at the laboratory of Palaeontology of the University of Zaragoza, we have identified five new taxa *Clethrionomys* (with the specie *C. glareolus*), *Terricola* (*T. lusitanicus-duocecimcostatus*), *Iberomys* (*I. cabreræ*), *Eliomys* (*Eliomys quercinus*) and *Myotis* sp. Also, this new study has enabled us to separate the species previously classified as *Microtus arvalis-agrestis* and let us confirm that there are representatives of both species, with a higher presence of *M. agrestis*. The newly identified species highlight times when the climate would have a certain Mediterranean control and more warm climatic conditions, as well as times of development of forest zones, probably riverine forest zones.



## PRELIMINARY STUDY OF THE SMALL MAMMALS ASSEMBLAGE FROM THE LATE MIOCENE OF DOLHEȘTI 1 (MOLDAVIAN PLATFORM – ROMANIA)

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### Keywords

Small Mammals, early Turolian, Late Miocene, Moldavian Platform, Romania



The small mammals assemblage from the Late Miocene locality Dolhești 1 of the Moldavian Platform presents the occurrence of specimens from three different orders: Rodentia, Lagomorpha, and Eulipotyphla. Dolhești 1 is located south of Iași county, in the northeast part of Romania. Approximately one ton of sediment was screen-washed, using stable sieves, to collect the fossils. The most important fossil elements identified in the locality were the teeth of small mammals. More than 30 teeth were identified belonging to seven taxa: *Vasseuromys pannonicus*, *Csakvaromys bredai*, *Neocricetodon progressus*, *Neopetes* sp., *Castromys* sp., *Ochotona kalfense*, *Schizogalerix sarmaticum*, being rodents the most diverse group. The age of the small mammals assemblage is interpreted as Late Miocene, early Turolian (MN 11), based on the presence of *Vasseuromys pannonicus*. The genera *Vasseuromys*, *Neopetes*, and *Castromys* are reported for the first time in the Late Miocene of Romania. The diversity of this faunal association represents an advantage for the interpretation of the palaeoenvironment. Furthermore, the discovery of these taxa constitutes an important contribution to the study of small mammals from the Late Miocene of the Moldavian Platform.

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## A REVIEW OF THE MACARONESIAN MURIDS

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### Keywords

Macaronesia, *Canariomys*, *Malpaisomys*, *Mus*, *Rattus*



Macaronesia is a region formed by archipelagos of volcanic origin (the Azores, Madeira, Savage Islands, the Canary Islands and Cape Verde), located in the mid-Atlantic, and near to the northwest of the African continent. The family Muridae (Mammalia: Rodentia), with a nearly cosmopolitan distribution, could arrived at Macaronesia in two ways: Naturally (the rafting hypothesis), and facilitated by humans in their voyages of exploration. Within the murid biodiversity of the Macaronesia, the Canary archipelago stands out for being the unique in which extinct endemic species of this group are found. There are three extinct species, *Malpaisomys insularis*, *Canariomys bravoï*, and *C. tamarani*. Murids of the genus *Canariomys* lived during the Pleistocene and Holocene, on the islands of Tenerife (*C. bravoï*) and Gran Canaria (*C. tamarani*). *M. insularis*, known as lava mouse, was located on the islands of Lanzarote, Fuerteventura, and La Graciosa, also in sites of Pleistocene and Holocene age. Besides, fossil remains of a large house mouse (*Mus musculus*) were found on the island of Madeira, which was probably brought by humans before Portugal conquered this island, since the datings of the bones place it around the year 1036 AD. The genera *Mus* and *Rattus* have been found in all the archipelagos, but not in all the islands. In this work we make a bibliographical review on the endemic and introduced murids that have arrived on the Macaronesian islands, the possible reasons for the extinctions of the species, and the deposits in which they can be found.



## A NEW SPECIES FROM THE MIOCENE OF COLORADO SHEDS LIGHT ON THE EVOLUTION AND ANCESTRAL ECOLOGY OF GEOMYOIDEA

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### Keywords

Body size, Geomorpha, Hemingfordian, Locomotion, Phylogenetics

Geomyoid rodents, including the living heteromyids and geomyids, are one of the most species-rich rodent groups in North America and display an incredible ecological disparity. Their fossil record is equally diverse with over 200 species recorded since the Oligocene. Despite this rich fossil record, the evolution of geomyoids and their relatives (together the clade Geomorpha) remains poorly understood. The taxonomic affinities of many species remain enigmatic and several taxa have been assigned to various families, alternatively considered clades or paraphyletic, or moved in and out of the crown group. Recent phylogenetic analyses have started providing answers to some of the many questions that plague geomorph systematics, but they have also showed conflicts with analyses of extant taxa based on molecular data. I offer one possible solution to these conflicts with an updated phylogenetic framework integrating morphological data for extant and fossil taxa and a backbone tree constraint from molecular data. Included in the tree is a new fossil from Colorado, which represents a new, very large, stem geomyoid species. The completeness of this new material, including a complete astragalus, enables the exploration of the ancestral locomotion of geomyoids. I use a training set of living and extinct rodents to infer the locomotion for the new species and 20 other fossil geomorphs using phylogenetic comparative methods. My results support a semi-fossorial ancestral ecology. This is consistent with predictions from ancestral character state reconstructions based on extant taxa that living pocket mice represent a reasonable model of the ancestral bauplan of geomyoids.





## TAPHONOMY OF MICROMAMMALS CONSUMED BY THE ACHALA FOX (*LYCALOPEX CULPAEUS SMITHERSI*) IN CÓRDOBA, ARGENTINA. TESTING FOR SEASONAL PATTERNS

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### Keywords

Taphonomy, Micromammals, Digestion, Actualism, Carnivores

Carnivorous mammals generate specific prey bone accumulations, including scats containing ingested remains, namely composed by microvertebrates. Here we present an actualistic study of the micromammals consumed by the Achala fox (*Lycalopex culpaeus smithersi*), endemic to the Pampa de Achala plateau (2000 masl average, 31°36'S, 64°51'W) in the mountains of Córdoba, Argentina, including previously unpublished samples. While the taphonomic patterns characterizing this canid were previously described, the aim of this new study is to assess whether they were affected by yearly seasonal changes. In order to do that, we compare the taphonomic patterns on the bones produced during the dry and wet seasons, based on 172 faeces collected during 2003, 2005 and 2007. The canid *Galea leucoblephara* was the main prey in both seasons, followed by several cricetids. The average relative anatomical abundance was 18.97% in the wet season and 22.3% in the dry one. Cranial elements were the most abundant ones in both seasons, followed by a great proportion of proximal limb elements and pelvis just in the dry season. A high degree of fragmentation was observed in skulls and jaws, with no significant differences between seasons. Notably, light digestion was dominant, but it reached strong and extreme levels in some elements throughout the year. In spite of the intra-annual environmental differences, no significant taphonomic variations are observed. These results contribute to the understanding of the taphonomy of micromammals consumed by this carnivore under different environmental conditions, and therefore, they are relevant to interpreting the formation of the fossil record.





## THE HERPETOTHERID (METATHERIA, MAMMALIA) FROM THE EARLY EOCENE OF SILVEIRINHA (PORTUGAL)

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### Keywords

Ypresian, MP7, Taxonomy, Palaeobiogeography, *Peratherium*



Silveirinha is one of the best-known mammalian sites from the Cenozoic of Portugal and the European Eocene. This locality is located 15 km South of Figueira da Foz (Baixo Mondego region, Coimbra). Silveirinha is of vital importance for the study of early Eocene mammals because it has yielded a high diversity fossil assemblage with more than 30 taxa, and it is the type locality of 11 mammal species. The age of this site remains controversial, since it has been attributed to either the late Palaeocene or the earliest Eocene. The mammal faunas are a combination of primitive elements typical of the Palaeocene, together with more modern ones that indicate the early Eocene. This association agrees with a more basal Ypresian age (near the Palaeocene-Eocene boundary), specifically MP7, making of Silveirinha the oldest European vertebrate site of Eocene age. Among the mammals present in Silveirinha there are many of American origin that migrated via Europe during the Palaeocene-Eocene Thermal Maximum (taeniodonts, triisodontids, or *Diacodexis*), in particular representatives of the family Herpetotheriidae, and more specifically of the genus *Peratherium*, which was present in both continents during the Ypresian. Specifically, at Silveirinha, appears the species *Peratherium* cf. *constans*; although according to the literature those remains could actually belong to a new species. This study will re-examine the materials of this family at Silveirinha, in the light of the new literature, and attempt to precise its taxonomy.



## BATS FROM ENROUANE (PHOSPHORITES DU QUERCY, FRANCE): HIGH BIODIVERSITY IN EARLY TIMES

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### Keywords

Mammalia, Chiroptera, Eocene, Priabonian, karst fill



The Quercy area is a limestone plateau in the southwestern part of the French Massif Central (Causses du Quercy), famous for its phosphate karstic fillings known as 'Phosphorites du Quercy'. This rich fossiliferous area is known since the 19th century when fissure fillings rich in phosphatic ore deposits were commercially exploited and abundant fossil remains were found in most of them. Here, we describe for the first time the bat assemblage from a new karstic filling known as Enrouane (Montricoux, Tarn et Garonne). It is rich in mammalian remains, including, besides bats, primates, carnivores, artiodactyls, and rodents. The age of this site based on the mammal association is MP17b-18a (Priabonian, late Eocene). Three sites have been found in the Enrouane karst fill, but bat remains are only present in Enrouane 1 and 3. The site where most of the remains have been recovered is Enrouane 1, where the following species were identified: two species belonging to the emballonurid bats, specifically of the genus *Vespertiliavus*, *V. bourguignati* and *V. disjunctus*; six different hipposiderid species, four of them belonging to the genus (subgenus) *Hipposideros* (*Pseudorhinolophus*), *H. (P.) morlotti*, *H. (P.) russelli*, *H. (P.) tenuis* and *Hipposideros* (*Pseudorhinolophus*) sp., in addition to *Palaeophyllophora* cf. *parva* and *Vaylatsia astruci*; and finally, one species belonging to the family Mixopterygidae, *Carcinopteryx trassounius*; and a molossid *Cuvierimops parisiensis*, which is the only bat found so far at Enrouane 3. The high diversity of bats found at the Eocene site of Enrouane shows that from the beginning of the history of this order, it was a very diverse group.



## THE INNER EAR OF CAVIOMORPH RODENTS: ALLOMETRY, SYSTEMATICS AND APPLICATION TO EXTINCT GIANT TAXA FROM THE WEST INDIES

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### Keywords

Geometric Morphometrics, Allometry, Systematics, Bony Labyrinth, Caribbean Islands

West Indian caviomorph rodents dominate the terrestrial mammalian fauna of the Caribbean archipelago with their past and current diversities. Many of these species have recently become extinct, including the emblematic giant forms known as Heptaxodontidae endemic to these islands. The higher-level systematics and content of this family have been widely disputed for decades without reaching a consensus. In this study, we analyze the allometric and phylogenetic signal of the inner ear of caviomorph rodents to address the phylogenetic affinities of the heptaxodontids. We assembled an exhaustive taxonomic sampling (N = 100) of extant North and South American caviomorphs and a wide array of West Indian forms, including octodontoid echimyids (extant and extinct capromyines, as well as extinct heteropsomyines), and some of the heptaxodontid subfossil taxa such as *Amblyrhiza*, *Clidomys*, and *Elasmodontomys*. Geometric morphometrics, comparative phylogenetic methods (*i.e.*, PGLS) and quantification of the phylogenetic signal of the bony labyrinth using Blomberg's K-statistic were employed to explore shape differences of the inner ear and their potential systematic implications. Our results show that i) allometry is a major contributor to shape variation in the bony labyrinth; ii) shape variation bears a strong phylogenetic signal, providing diagnostic characters for Caviidae and Erethizontoidea and iii) *Amblyrhiza* and *Clidomys* would be closely related and have potential phylogenetic affinities with Chinchilloidea. *Elasmodontomys* remains a problematic taxon as it exhibits inner ear features that are consistent with either Chinchilloidea and Octodontoidea among Octochinchilloi, depending on how the allometric component is evaluated; thus its suprafamilial position is uncertain.





## ECOLOGICAL DYNAMICS OF RODENT COMMUNITIES IN THE HOLARCTIC DURING THE SPREAD OF OPEN HABITATS

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### Keywords

Rodentia, Community Ecology, Locomotion, Diet, Hypsodonty



The spread of open habitats during the early Neogene drove major evolutionary changes in terrestrial mammals. While the classic studies of mammal evolution during the rise of grasslands focused on ungulate herbivores, recent studies have shown that small mammals respond differently and perhaps with greater sensitivity to these habitat changes. The acquisition of hypsodonty and cursoriality by large herbivores in the middle Miocene is a much more uniform and consistent pattern than the mosaic response of small mammals. Studies of North American rodents demonstrated that the evolution of dietary and locomotor responses to open habitats occurred much earlier in rodents, with the most dramatic changes in ecology in the late Oligocene and early Miocene. To further explore the rodent ecological response to the spread of open habitats, I have used the NOW database records of rodents from Europe, Asia, and North America in combination with data from the literature on diet and locomotor habits. In comparison with North America, Eurasia sees a substantially later and less dramatic rise in open habitat specialists through the Neogene. Dental morphology in particular does not see dramatic changes in Eurasian communities until the latest Miocene, and locomotor changes toward burrowing and hopping characterize only a small fraction of European communities even in the Pliocene and Pleistocene. Asian rodent diversity includes more taxa with open-habitat locomotor styles than does Europe, but still far fewer than we find in North America. These continent-scale differences in ecological responses to habitat change illustrate the sensitivity of rodents to evolving landscapes, which makes them key to understanding how natural ecosystems respond to human impacts.



## EVIDENCE OF MULTIPLE PRODUCERS IN *YAVICHNUS INIYOOENSIS* BURROWS FROM THE EARLY OLIGOCENE OF SOUTHERN MEXICO

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### Keywords

Bioglyphs, *Gregorymys*, Oaxaca, Santiago Yolomécatl, Chilapa Formation

*Yavichnus iniyooensis* is a rodent fossil burrow system probably produced by the geomyid rodents *Gregorymys veloxikua* and *G. mixtecorum*. It has been described from the early Oligocene Chilapa Formation strata, which crop out in the outskirts of Santiago Yolomécatl of Oaxaca. In several specimens, short, straight, paired marks on the external surface of the burrow fill can be observed; these are interpreted as the marks left by rodent incisors. An exploratory analysis of the measurements of the width of such paired marks in a large system revealed two groups, one ranging from 2.2 to 3.2 mm (mean 2.95 mm; n = 12) and another with a range of 3.4 to 5.3 mm (mean 3.99 mm; n = 31). A U Mann-Whitney test showed that there are statistically significant differences between the medians of each group. The record of two different groups of incisor marks in a single burrow system suggests that diverse individuals of different sizes and different species (*G. veloxikua* and *G. mixtecorum*) produced *Yavichnus iniyooensis*, given that bones of both species have been collected from the same burrows. This contrasts with the solitary behavior of extant geomyids. Taphonomic features of the paired marks are similar in both groups and have the same depth, suggesting that they were produced in a short time.





## INTERSPECIFIC VARIATION IN TWO EARLY OLIGOCENE GOPHERS (RODENTIA: GEOMYIDAE) FROM SOUTHERN MEXICO

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*Gregorymys*, Oaxaca, Santiago Yolomécatl, Chilapa Formation



The entoptychines *Gregorymys veloxikua* and *G. mixtecorum* are some of the most abundant fossils in the early Oligocene Iniyoo Local Fauna, and are amongst the oldest members of the Family Geomyidae. Such abundant material allowed us to explore morphological variation in both species. Studied specimens were collected from the upper unit of the fluvio-lacustrine Chilapa Formation that crops out in Santiago Yolomécatl. The sample size in *G. veloxikua* varies from seven to 95 specimens, depending on the analyzed skeletal element, whereas in *G. mixtecorum* sample size ranges from three to 35 specimens. Although there is some overlapping in the ranges of linear measurements, Mann-Whitney U tests of the length and the width of the P4 and of the length of p4-m3, the length of the lower diastema, the width of the upper and lower incisors, the width of the M1-M3, and some skull measurements (diastema length, mandible depth, palatal width), showed that there are statistically significant differences between the medians of each species ( $p < 0.05$ ). Only in the length of the M1-M3 showed no significant differences. Also, some new qualitative character states could be observed: the base of the enamel in the teeth of *G. veloxikua* could be undulated or flat, and there is a faintly developed anterolabial cingulid in the slightly worn m1-m3 of this species. Additionally, the deciduous p4 and the unworn molars are recorded for first time in *G. mixtecorum*. This new information will allow a better taxonomic and ecological characterization of both Oligocene species from Mexico.



## STABLE ISOTOPE ANALYSIS OF *MICROTUS* SPP. FROM NEAR EAST MID-LATITUDES: IMPLICATIONS FOR PLEISTOCENE CLIMATE IN THE LAST GLACIAL

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Mediterranean Levant, Caucasus, Paleoecology, Zooarchaeology



Since the Mediterranean Levant and Caucasus are situated in mid-latitudes, climate oscillations during the Last Glacial Period (LGP, c.115–12 Kya) are not as pronounced as in northern latitudes. A primary question is whether the LGP was cold and dry or cold and wet. In mid-latitudes, most vegetation is C<sub>3</sub>-dominant. Therefore,  $\delta^{13}\text{C}$  varies according to precipitation, and not changes between C<sub>3</sub> and C<sub>4</sub> vegetation. To test if voles can be used as palaeoecological proxies in mid latitudes, teeth were sampled from across modern Israel and correlated with GIS-derived climatic data, developing a modern model of the paleoecology. The results of the modern Israel samples indicate a positive correlation between  $\delta^{13}\text{C}$  and mean annual rainfall with an average of  $-15.47 \pm 1.277$  (n=39), confirming previous observations that more enriched  $\delta^{13}\text{C}$  indicate higher mean annual precipitation. Next, vole teeth were sampled from Rantis (160 - 120 Kya), Israel, and Dzudzuana (ca. 40 Kya), Republic of Georgia. The results indicate that carbon values for both fossil sites were enriched compared to modern voles (Rantis n=9,  $-9.8 \pm 0.25$ ; Dzudzuana n=19  $-7.2 \pm 0.82$ ), suggesting that these Pleistocene sites had an increase in mean annual precipitation compared to modern populations. These results support the hypothesis that glacial periods in the area were cold and wet rather than cold and dry and demonstrates the value of vole stable isotopes as palaeoecological proxies in mid-latitude regions such as the Levant and Caucasus.



## ACTUALISTIC TAPHONOMY OF MICROVERTEBRATES INGESTED BY THE OWL *TYTO FURCATA* IN A FORESTED AREA. IMPLICATIONS FOR THE FOSSIL RECORD

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### Keywords

Taphonomy, Microvertebrates, Digestion, Pellets



Microvertebrates are common prey of nocturnal raptor birds, which usually have the ability to ingest whole prey and subsequently expel the partially digested remains of bones, teeth, hair and feathers in regurgitated pellets. Based on frames of reference built out of actualistic taphonomic studies, it is possible to identify the type of raptor bird involved in the fossil record by categorising the degree of digestive corrosion, as well as the degree of breakage, in microvertebrate skeletal elements. Taphonomy can thus help assess biases caused by these agents, as well as paleoecological information, for which neotaphonomic studies are crucial. Here we present one such study, done on skeletal remains (total MNE= 7361) from modern pellets produced by the strigiform *Tyto furcata*, recovered in winter 2021 at Villa Padre Monti (Tucumán, Argentina), a locality associated with Yungas and Chaco Serrano forest. The aim was to increase the samples characterising this taphonomic agent under different environmental conditions, as so far it was known mainly from dry areas. Prey consisted of cricetid rodents. The analysis showed good skeletal preservation and a fairly complete anatomical representation, low levels of fragmentation of cranial and postcranial elements, and a high proportion of skeletal elements with little or no signs of digestive corrosion, as defined by Andrews. Moderate and severe digestion was only observed in a few elements. Our results are in agreement with other studies carried out on *T. furcata* populations from dryer environments, where this raptor species has been classified as a light bone modifier.



## NEW DATA ON THE DENTAL REPLACEMENT IN DJADOCHTATHERIOID MULTITUBERCULATE MAMMALS

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### Keywords

Multituberculata, Djadochtatherioidea, *Chulsanbaatar*, *Tombaatar*, dentition



The multituberculates show a typical diphyodont dental exchange, that is, the replacement of incisors and premolars. The dental replacement pattern was studied in paulchoffatiid and taeniolabidid multituberculates, but it is still poorly known in the Late Cretaceous Djadochtatherioidea. Here we present new data on the deciduous dentition and dental replacement in the two djadochtatheriids *Chulsanbaatar* and *Tombaatar*. The morphology of the new specimens has been studied with the help of CT-scanning performed at the NanoFun Lab (The Institute of Paleobiology, Polish Academy of Sciences), with resolution of 35 µm. The scans were processed further using 3D Slicer ([www.slicer.org](http://www.slicer.org)) software for 3D image analysis. Two specimens tentatively assigned to *Tombaatar* are different juvenile ontogenetic stages, indicating the apparent diachrony of the dental replacement sequence. Interestingly, the smaller of the studied specimens shows a more advanced dental replacement than the larger one. Both specimens have complete sets of deciduous and permanent incisors (dl2, I2, dl3, and I3) in the premaxilla, fully erupted permanent premolars, and erupting M2. The mandible of the larger specimen still shows the presence of di1 along the i1, whereas the smaller specimen has already shed the deciduous lower incisor. Further, two new skulls of *Chulsanbaatar* sp. display a different pattern of the premolar replacement from that suggested previously for the 'Late Cretaceous-Tertiary' multituberculata taxa. Thus, the exchange sequence is more likely the P2>P3>P1 than P1>P2>P3. Also, the incisor replacement timing is slightly different than in taeniolabidids. Our material provides new information on the evolution of the dental replacement pattern in the djadochtatherioid multituberculates, suggesting some diachrony of the process.



## ANALYSIS OF DENTAL MICROWEAR AND ENAMEL THICKNESS IN *HETEROXERUS RUBRICATI*: UTILITY AS INDICATORS FOR THE CHARACTERIZATION OF ARIDITY

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### Keywords

Miocene, Madrid Basin, Calatayud-Montalbán Basin, Xerini, Sciuridae



Dental microwear is the set of microscopic marks that form on the surface of the tooth during mastication. Quantifying its spatio-temporal variation within the same species allows us to know the variation of diet according to the availability of resources and the amount of grit ingested. Additionally, the thickness of dental enamel allows us to know the dietary preferences and possible environment of fossil species. In this study, upper molars of *Heteroxerus rubricati* from the Miocene basins of Madrid and Calatayud-Montalbán (Spain) have been used to analyze geographically and temporally the microwear and enamel thickness changes. To quantify microwear, four types of marks have been quantified: fine and wide scratches, and small and large pits. The results show a greater number of fine scratches and large pits in the Calatayud-Montalbán Basin, and a higher frequency of small pits in the Madrid Basin. A high frequency of small pits is associated with the consumption of soft seeds and an arid environment with a high amount of grit. This is consistent with greater aridity in the Madrid Basin during the Aragonian as proposed based on mammal associations. Conversely, in the squirrels from the Calatayud-Montalbán Basin, the microwear is similar to that of forest species. However, regarding enamel thickness, the results are not conclusive, and it is necessary to use a larger sample. Our results demonstrate the usefulness of small pits as indicators of the aridity of the environment and allow us to infer the relative aridity of different sites without other paleoclimatic data.



## SMALL MAMMAL FAUNAL EVOLUTION THROUGH THE CENOZOIC OF OREGON

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### Keywords

Climate Change, Hysodonty, Locomotion, Eocene-Oligocene Transition, Middle Miocene Climatic Optimum



The records of Cenozoic life preserved in the John Day and Crooked River Basins of Oregon are among the best in the world. A well-studied, dated sequence of strata and a wealth of fossils document the evolution of floras and faunas over nearly 50 million years of time. Independent lines of evidence (paleosols, paleobotanical records, and ecometric analysis of mammal teeth) provide evidence of changes in climate and habitat through the sequence. These basins include mammals ranging from Uintan to Hemphillian in age, allowing detailed study of the evolution of faunas over time. I used data from the NOW Database to code small herbivorous mammal taxa (127 species total from 5 orders) into tooth crown height and locomotor categories. Patterns of species richness within clades and abundances of attributes were compared through time. After the Eocene-Oligocene transition, small ungulates became less common, rodents and lagomorphs shifted to primarily higher-crowned taxa, and cursorial rabbits and burrowing rodents appeared. Through the late Oligocene and early Miocene, open habitat specialists (with high-crowned teeth, burrowing, saltatory, or cursorial habits) became more common, while forest dependent groups (with low-crowned teeth, arboreal habits) declined. In the middle Miocene, higher-crowned taxa and burrowing rodents diversified, which may be attributable to the massive volcanic activity in the region at the time. And the late Miocene is dominated by high-crowned taxa, similar to species inhabiting the Columbia Plateau today. This detailed record reveals dynamic faunal evolution driven by changing climate and geologic influences.



## SHAPE VARIATION IN THE TEETH OF *GREGORYMYS MIXTECORUM* AND *GREGORYMYS VELOXIKUA* (MAMMALIA: RODENTIA) FROM THE EARLY OLIGOCENE OF OAXACA, SOUTHERN MEXICO

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### Keywords

Rodentia, Teeth, Geometric Morphometrics, Landmarks, Variation



The geomyids *Gregorymys veloxikua* and *Gregorymys mixtecorum* are the most southern species of the subfamily Entoptychinae in North America. Specimens of the two species were collected from the same burrows and the same early Oligocene strata (Chilapa Formation), outcropping in the outskirts of Santiago Yolomécatl in northwestern Oaxaca. Shape variation of teeth was qualitatively observed during the description of both species. Accordingly, since it was previously determined that geometric morphometric analyses allow the identification of entoptychines, we used this technique to quantitatively evaluate the shape variation in 39 teeth of *G. veloxikua* and 18 teeth of *G. mixtecorum*. Variation was evaluated in slightly worn teeth (stage of wear one -SW1-) and moderately worn teeth (stages of wear three and four -SW3, SW4-). As in the previous work, three landmarks and 40 semi-landmarks were used in teeth with SW3 and SW4, whereas six landmarks and 34 semi-landmarks were used in teeth with SW1. Principal component analyses showed that there is a wide variation in teeth shape within species and between species. Goodall's F statistic results showed that there are significant mean shape differences between both species in the P4 in SW1, the M1 in SW4, the p4 in SW1, and the m2 in SW3 and SW4. The mean shape could not be evaluated in the remaining tooth positions given its limited sample size (<3 specimens). The observed teeth shape differences (as well as their different size) would allow the exploitation of different feeding resources between both species, allowing their coexistence.



Modern and ancient animal traces have long captured the imagination of scientists and non-scientists alike. Vertebrate trace fossils, e.g., footprints, burrows, scratch marks, and nests, among others, inform our understanding of different aspects of anatomy, function, locomotion, ethology, and ecology of their tracemakers. These may be complementary to and integrated with the body-fossil record and assist in shedding light onto macroevolutionary processes and community dynamics.

The study of vertebrate trace fossils has progressively required a multifaceted approach in order to extract reliable information from the ichnological record. In recent years and increasingly, vertebrate ichnology has become a multi-disciplinary and technology-enhanced field of investigation. The increasing focus on multifaceted and technologies-rich methodologies has led to the melding of diverse paleontological and geological fields, creating new fields, e.g. in comparative biology. These cutting-edge methodologies are available to answer different ichnological questions, ranging from the processes of trace formation and preservation to the paleobiology of producers. Continued advances in neoichnology directly assist in refining our understanding of how traces formed in different environments, by different animals, and how they can be used to interpret the vertebrate fossil record in a more dependable and parsimonious way. Paleobiological inferences are more difficult to achieve and depend on integrating external data from sedimentology, biostratigraphy, the osteological record, and the adopted epistemological approach to producer identification.

This Thematic Session is aimed at providing a critical roundup of different approaches and methodologies adopted in vertebrate ichnology to solve paleobiological issues in vertebrate evolution. Communications dealing with theoretical issues, analysis, and discussion of traces, tracemaker attribution, and other paleobiological aspects, in addition to adding to the discussion of classical and cutting-edge methodologies are welcome. Main topics may include, but are not limited to, approaches for producer identification, disparity in the ichnological record, producer behavior, paleobiogeography, comparison and integration with the body-fossil record, paleoecology, neoichnology, and evolution.

# Vertebrate ichnology: from traces to tracemakers

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## Thematic Session





## MODERN TRACES OF THE AMERICAN ALLIGATOR (*ALLIGATOR MISSISSIPPIENSIS*) AS A GUIDE FOR INTERPRETING CROCODYLOMORPH TRACE FOSSILS

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### Keywords

Ichnology, Crocodylomorphs, Paleoecology, Behavior, Tracks



Crocodylomorphs, which originated during the Late Triassic and today are represented by crocodylians, are mostly known through their body fossils. Although these crocodylomorph fossils are preserved in sedimentary environments ranging from terrestrial to freshwater to marine, they are often fragmented and were transported away from their original ecological settings. In contrast, crocodylomorph trace fossils, such as footprints, burrows, and nests, handily supplement body-fossil data while clarifying behaviors in a paleoecological context. Hence the study of modern crocodylomorph traces are a valuable tool for recognizing and interpreting their ancient behaviors. Of modern tracemakers, the American alligator (*Alligator mississippiensis*) is arguably the best to study, owing to its abundance and diverse behaviors, resulting in ichnological richness. Moreover, alligators on Georgia-coast barrier islands are facies-crossing tracemakers, leaving tracks and other traces in sedimentary environments ranging from maritime forests to freshwater ponds, salt marshes, back-dune meadows, coastal dunes, and intertidal beaches. Trackways can also represent ontogenetic differences in behaviors, and habitual movements form trails connecting different ecosystems. Alligator burrows, which can be more than 1 meter wide and several meters long, are used for denning newly hatched young, but also serve as multigenerational safe havens from droughts, winters, fires, storms, and other environmental hazards. Lastly, my actualistic studies of alligator traces presented here provide reality checks on their preservation potential, particularly with trackways in coastal environments that are readily erased by bioturbating invertebrates or wind, tides, and waves. All of these modern alligator-provided insights can thus aid in the study of crocodylomorph trace fossils.



## THE OLDEST FOSSIL FOOTPRINTS OF A BIRD-LIKE ANIMAL (LATE TRIASSIC, SOUTHERN AFRICA)

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### Keywords

Late Triassic, southern Africa, *Trisauropodiscus*, proto-avian



Footprint morphology reflects the anatomy of the trackmaker's foot providing direct evidence for the animal's behaviour. Consequently, fossil tracks can be used to infer ancient diversity and evolutionary trends. This is particularly useful for deep-time intervals during which the early history of an animal group is reliant upon limited fossil skeletal material. Fossil tracks of birds and theropods, the co-existing dinosaurian ancestors of birds, co-occur in the rock record since the Early Cretaceous. However, the evolutionary transition from dinosaur to bird and the timing of the birds' origin remain the subject of debate. Skeletal remains of the basal-most bird *Archaeopteryx* are Late Jurassic, and though tracks with tentative bird affinities are known from earlier in the Jurassic, they are attributed to dinosaurs. Tracks with "proto-avian" characteristics, attributed to the ichnogenus *Trisauropodiscus*, from the Late Triassic to Early Jurassic Stormberg Group (main Karoo Basin, southern Africa) were reported on in the mid-1900s. These initial reports have been dismissed in the literature for two main reasons: the stratigraphic origin of the tracks was uncertain, and the tracks were primarily documented as interpretive sketches. In this contribution, we revisit *Trisauropodiscus* bearing outcrops and collected cast material to: 1. Refine the stratigraphic position of *Trisauropodiscus* ichnosites, and 2. Quantitatively assess the track morphology. Our findings support that *Trisauropodiscus* is known since the Late Triassic (c. 215.4 Ma, Maphutseng ichnosite) and that certain species of the ichnogenus have demonstrable avian affinities. Therefore, these tracks are the oldest evidence for a bird-like animal.



## THE FIRST RECORD OF TETRAPOD FOOTPRINTS FROM THE UPPER PENNSYLVANIAN OF THE OUED ZAT BASIN (HIGH ATLAS, MOROCCO)

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### Keywords

*Batrachichnus*, *Limnopus*, Biostratigraphy, late Paleozoic, NW Africa



Tetrapod footprints from upper Pennsylvanian units (latest Kasimovian to early Gzhelian) of the Oued Zat Basin have been collected, analyzed and assigned to the ichnogenera *Batrachichnus* and *Limnopus*. The fossil record consists of small to medium ca. 3 cm in size, poorly to well-preserved specimens. They are predominantly 18 isolated footprints; the trackways are scarce. The described ichnogenera, usually referred to small to medium-sized temnospondyls, which are well known from the Euramerican area, and previously recorded from NW Africa. The present study is the first description of the ichnoassemblages along with the analysis of lithofacies from a 300 m thick sedimentary succession in the Oued Zat Basin. The footprint-bearing beds consist of mud-draped sandstone, siltstone and laminated claystone. The bedding planes exhibit raindrops, mud cracks and microbially induced sedimentary structures that indicate alternating wet and dry conditions. Furthermore, the tetrapod footprint assemblages co-occur with fossil plants, which are mostly impressions of walchian conifers. The analyzed ichnotaxa belong to the *Dromopus* biochrone, which ranges from the late Carboniferous (late Pennsylvanian (Gzhelian) to early Permian (Artinskian). Whereas, the late Pennsylvanian macrofloral association of the Oued Zat constrains its age to the late Pennsylvanian Stephanian B/C. Lithofacies and fossil associations point to a fluvio-lacustrine system. Further investigations might contribute to a better understanding of the evolution, biodiversity and biogeography of the late Paleozoic tetrapod ecosystem, as well as establishing a biostratigraphic framework of the study area.



## CARCHARODONTOSAURS IN THE APULIAN CARBONATE PLATFORM? EVIDENCE FROM THE MOLFETTA DINOSAUR TRACKSITE (LOWER CRETACEOUS, SOUTHERN ITALY)

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### Keywords

lower Albian, theropods, trackmakers, palaeobiogeography, Gondwana



The lower Albian track-bearing surface of the San Leonardo quarry (Molfetta, Apulia) is characterised by more than 800 dinosaur footprints. Six well-preserved bipedal trackways are attributed to theropods up to 6.5 m long, according to the formulas proposed in the literature (*i.e.*, Hip Height = 3.06 FL1.14, Body Length = 4 H). They consist of medium- to large-sized, weakly mesaxonic and robust tridactyl footprints. Morphological comparison with Upper Jurassic and Lower Cretaceous theropod tracks from surrounding areas, supported by morphometric analyses, points out a highest affinity with the specimens from North Africa. Nevertheless, a set of unique characters led to the establishment of the new ichnospecies *Jurabrontes melphicticus*. The relevance of this occurrence in a shallow-water domain led to an in-depth research aimed at looking for the most suitable theropod trackmaker of the Molfetta ichnoassemblage. We virtually restored the autopod of the trackmaker, on account of the morphological details recognised in the tridactyl tracks (*i.e.*, metatarsal-phalangeal and phalangeal pad traces and claw marks) and considering the arthral condition of the theropods autopods. A morphological comparison was performed with the known autopods of the main theropod clades, according to the synapomorphy-based, the phenetic and the coincidence correlation methods. Additionally, we provide morphometric tests, based on a multivariate matrix including the osteometric parameters of all the detected autopods. The results, obtained by combining the above mentioned qualitative and quantitative approaches, point to hypothesise a carcharodontosaurid as possible trackmaker for *J. melphicticus* and suggest a Gondwanan origin for the theropods of Molfetta.



## PALAEOPATHOLOGIES IN ICHNOLOGY. THE CASE STUDY OF HUNGARIAN MIOCENE RHINO TRACKS

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### Keywords

Vertebrate Ichnology, Paleopathology, Rhino, Miocene, Hungary



A vast vertebrate track record is recorded through the Phanerozoic, from the first land tetrapods to modern animals. However, the track record of malformed or injured animals is extremely rare. A few localities are known with trackways of, for example limping dinosaurs or animal with missing digits; but this kind of ichnological record becomes even more scarce in the Cenozoic. This rarity sets against the number of injured animals that can be observed in the wild. The re-examination of the Ipolytarnóc material (Early Miocene, North Hungary), recently carried out under a Synthesys visit, from a slab housed at the Supervisory Authority for Regulatory Affairs, previously Hungarian Geological Institute, lead to the discovery of 3 “non-standard” tracks. They belong to the ichnogenus *Rhinoceripeda tasnadyi*, attributed to a medium-to large-sized “hornless” Miocene rhinoceros. In these tracks, the hoof of the left digit III appears to be split, rather than oval, at approximatively half of its width, thus giving a peculiar, almost tetradactyl appearance to the footprints. The deformation due to overprinting by other animals is excluded because of the number of tracks showing the same variation. Importantly, it was possible to identify this injury/malformation because of the hundreds of *R. tasnadyi* tracks accessible at Ipolytarnóc. The large number of tracks account for the standard variability of the morphology at Ipolytarnóc and for the detection of abnormalities. If the track record was limited, it would not be possible to recognise those differences as ichnopathologies and, as a result, a different trackmaker may be assessed.



## WHO “DROPPED” THIS? NON-DESTRUCTIVE METHODOLOGY FOR THE STUDY AND TAXONOMIC ASSIGNMENT OF CARNIVORE COPROLITES

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### Keywords

Droppings, Iberian Peninsula, micro-CT scanning, Quaternary, 3D model



The shape, size, and content of droppings has long been used to identify their producers. Mammalian scats are very varied, but it is sometimes possible to differentiate faecal morphotypes and to link them to at least family level. Furthermore, since the diameter of the droppings is related to the size of the producer, it is sometimes even possible to identify it at genus or even species level. These features can be used in palaeontological contexts where scat producers are either extant or at least with close modern representatives, making it possible to perform morphometric comparisons to help identify the producer of the coprolites. Even when no extant or closely related representatives are available to obtain reliable identifications, useful information can be gained from studying coprolite content since it allows to draw conclusions about the diet of the producer or its behaviour. Microtomography is a useful technique that enables to analyse the interior of coprolites without destroying the specimens. By means of this technique it is possible to produce three-dimensional models of the coprolites and their contents, creating a useful digital replica. Using these methodologies, it has been possible to identify the probable producers of the coprolites collected in the fossil sites of Villanueva-1 (Middle Pleistocene, Palencia), Juan Labranz Cave (Late Pleistocene, Cuenca) and Buena Pinta Cave (Late Pleistocene, Madrid). These involve from small carnivores and scavengers to even bears, widening the range of coprolite producers in Spanish Quaternary sites, where only spotted hyaena coprolites are commonly identified.



## JUMPING IN SAND: THE EFFECTS OF VARIABILITY IN SAND MOISTURE CONTENT ON TETRAPOD TRACE FIDELITY

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### Keywords

Aeolianite, Tetrapod, Neoichnology, Substrate Variability, Hydrology



The Australian Quaternary tetrapod trace fossil record is largely limited to footprints preserved in coastal aeolianite/calcareous dunes. The ways in which trace faithfulness varies with water content in these sediments are poorly documented, particularly in an Australian context. In order to better predict substrate characteristics in fossil tetrapod trackways, we designed a mechanical kangaroo and made it 'hop' through sandy substrates of variable composition and water content. We also examined which hydrological conditions were most likely to result in a footprint being preserved prior to burial. Our results demonstrate that clayey sand, quartz sand and calcareous sand behave similarly up to 10% water content but that, with increasing water content, calcareous sand holds its shape longer than the other substrates. Greater than 20% water content results in complete loss of trace fidelity in all substrates tested. We also observed that trace fidelity was poor in dry sand, with large displacement rims present, and that ejecta volume was largest in all three substrates at 5% water content. Our experiments also demonstrated that salt spray on dry sand, followed by a heating/drying phase, created the ideal conditions for a crust to form, stabilising trace morphology. Our findings have important implications for identification of substrate conditions at time of imprinting in fossil tetrapod traces in sand and help establish the ideal conditions for footprint preservation in coastal sand dune environments.



## A NEW DINOSAUR TRACKSITE IN THE “EARLY PALEOZOIC” MAURITI FORMATION, ARARIPE BASIN, BRAZIL

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### Keywords

Footprints, Dinosaur, Mauriti Formation, Araripe Basin



Footprints in the Araripe Basin (an interior basin of NE Brazil) are previously known in the Mauriti Formation only from the Milagres ichnosite (Milagres County, Ceará State) on coarse to fine-grained sandstones. Since this formation is considered and mapped as Silurian-Devonian — despite the fact that no macro- or microfossils established its age — the presence of such footprints shows a temporal inconsistency. The dinosaur footprints found in a new ichnosite (Mauriti County, Ceará State) indicate a Mesozoic age for the Mauriti Formation, and due to the proximity of the nearby Rio do Peixe basins and to the similarity of their dinosaur tracks, a particularly Early Cretaceous age is herein suggested. This new ichnosite presents at least five isolated footprints of theropod and of indeterminate trackmakers. The two theropod footprints are tridactyl, mesaxononic with claw impressions. The rear borders of these footprints are angular. The other imprints are rounded depressions with no clear digit impressions, surrounded by displacement rims. The partial sandstone filling of the footprints is similar to the surrounding matrix. They range from 30-48 cm in length and 25-48 cm in width. The paleoenvironmental interpretation of the strata on where they are found is fluvial braided. The trackmakers could be the large theropods related to those ones already known in the Araripe Basin's Cretaceous formations. The importance of this new tracksite confirms the need to revise the age of the Mauriti Formation and the interested paleogeography, establishing a new stratigraphic framework to the lower successions of the Araripe Basin.



## MULTI-PHASE FILLING PROCESS IN THEROPOD AND SAUROPOD DINOSAUR FOOTPRINTS FROM THE CANDELEROS FORMATION AT VILLA EL CHOCÓN, PATAGONIA ARGENTINA

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### Keywords

Dinosaurs, Tracks, Candeleros Formation, Upper Cretaceous, Neuquén Basin

The area surrounding Villa El Chocón (Neuquén province, Argentina) constitutes a huge ichnosite where dinosaur footprints were reported from playa-lake facies of the Cenomanian Candeleros Formation. This unit stands out for its rich and diverse tetrapod body- and ichno-fossil record, the latter including footprints attributed to sauropods, theropods, ornithopods, and pterosaurs. Despite studies conducted on the ichnofauna, processes presiding footprints' formation and preservation were underinvestigated. A track-bearing surface, preserving large sauropod and tridactyl footprints attributed to theropods, was recently unearthed, allowing characterize how these tracks were formed and included into the geological record. Conformable contact between two horizons enabled identify the tracking surface that, as the underlying subsurface, was made up of fine-grained sands displaying wrinkle structures. Both sauropods and theropods, while crossing, broke the paleosurface, which was stabilized by microbial mat and in subaerial conditions. Producers' autopods passed through the underlying, medium- to coarse-grained sandy layers, to a depth of 50 cm maximum. Wide and thick displacement rims associated to tracks suggest high cohesiveness and plasticity of the substrate. A first filling event of the newly formed underprints started synchronously to autopodia recovery, with the detachment of sediments from the sole of producers' feet. Tracks remained temporarily uncovered and were finally blanketed by dark grey, micaceous silts displaying small-scale, cross-laminated ripples with symmetrical and straight morphology, sedimented in a lacustrine environment. Our reconstruction highlights the pivotal role that understanding of footprint formation and preservation plays in addressing questions about footprints ichnotaxonomy, as well as palaeobiology and palaeoecology of trackmakers.





## NEW ICHNOLOGICAL CLUES SHED LIGHT ON THE PERMIAN TETRAPOD FAUNA FROM “TORRE DEL PORTICCIOLO” (NW SARDINIA, ITALY)

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### Keywords

Reciprocal illumination, Tetrapod footprint, Guadalupian, Trackmakers, Pangaea

Ancient continental deposits bearing skeletal and ichnological tetrapod remains provide complementary information that improve our understanding of faunal composition in deep time terrestrial ecosystems. A suggestive case is represented by the uppermost Cisuralian-lowermost Guadalupian Cala del Vino Formation (Sardinia, Italy). Two 'pelycosaurs' (medium- to large- and giant-sized) and footprints referred to *Merifontichnus* isp. (medium-sized producer) were reported from silty-sandy sediments at approximately the same stratigraphic level within this unit. Newly recovered ichnological material enables corroborating the occurrence of *Merifontichnus* isp. and adding more footprint morphologies. The new record consists of five trackways and a plethora of traces (as overtracks, true tracks and undertracks), most of which were left by small-sized producers crossing a puddle that was filling up by muddy sediments, allowing the preservation of traces. A first morphology, found in association with raindrop prints, is represented by plantigrade, tetradactyl, wider than long footprints, with stout and rounded digit tip imprints, referred to *Limnopus* isp. A second morphology includes negatively rotated, longer than wide, tetradactyl pedal and pentadactyl manual prints, displaying slender and straight digit traces, referred to *Hyloidichnus* isp. A third morphology is represented by didactyl to tetradactyl pedal and manual prints with slender and curved digit traces referred to *Dromopus* isp. The new track record highlights different preservational demands for differently sized body- and ichnofossils. It adds tiny to medium-sized tetrapods, among which most likely temnospondyls, captorhinids, areoscelids and synapsids, to the late Cisuralian-early Guadalupian terrestrial palaeofauna of Sardinia, spurring further comparison with penecontemporaneous ecosystems across Pangaea.





## A NEW OCCURRENCE OF A THEROPOD TRACK FROM THE GUARÁ FORMATION (UPPER JURASSIC OF RIO GRANDE DO SUL, BRAZIL)

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### Keywords

Dinosaur, Sanga do Torneado, Ichnology



After their origin and early diversification in the Triassic, dinosaurs reached greater size and diversity during the Jurassic Period. In Brazil, the fossil record of Jurassic dinosaurs is comparatively scarce and limited to bone fragments from the Araripe and Jatobá basins, as well as tracks from the Guará Formation (Upper Jurassic, Paraná Basin). Spanning from the Brazilian Paraná state to northern Uruguay, the Guará Formation is a large sedimentary sequence of fine-grained to conglomeratic sandstones of fluvial and aeolian origin. The known ichnological record of this formation includes sauropod, theropod, ornithopod and ankylosaur tracks, as well as burrows of both vertebrates and invertebrates. Footprint preservation is predominantly in the form of undertracks, due to the low rock cementation subjected to erosion. However, in 2018 the first original theropod track was found in a creek at Sanga do Torneado outcrop, located in the outskirts of Rosário do Sul. This tridactyl, mesaxonic footprint measures 25 cm in length and 23 cm in width, showing a claw imprint in the digit III. Currently, 3D models, from photogrammetric work, are being utilized to aid in the identification of preserved anatomical traces which should prove useful in identifying the trackmaker. Additionally, a literature search for footprints and autopodia is currently underway for comparative analysis. Despite the difficulty to find and interpret the footprints preserved in the aeolian deposits, the newly reported findings highlights the great potential that Guará Formation holds in enhancing our understanding of the Jurassic dinosaur (ichno) fauna of Western Gondwana.



## MIDDLE JURASSIC DINOSAUR TRACKSITES FROM THE ISLE OF MUCK AND ISLE OF SKYE, SCOTLAND, UK, RECONTEXTUALIZE GEOLOGICAL DESCRIPTIONS OF LOCALITIES

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### Keywords

Dinosaur Footprints, Scotland, Middle Jurassic, Load Cast, Sauropod



The Middle Jurassic-aged Great Estuarine Group (GEG) of the Inner Hebrides, Scotland, UK, spans a range of depositional settings from fluvio-deltaic systems to brackish lagoons and nearshore marine environments. The most common vertebrate fossils from the GEG, dinosaur footprints, hint at a diversity of dinosaurs exceeding the corresponding body fossil record. Here, we report two new Scottish dinosaur tracksites. The first, Camas Mór, Isle of Muck, contains a varied ichnofauna dominated by sauropod tracks with some theropod tracks and an isolated ornithopod track. The site spans a transitional facies from the deltaic sandstones of the Valtos Sandstone Formation to the brackish lagoons of the Duntulm Formation with footprints occurring across multiple stratigraphic levels. The ichnofauna of the second tracksite, Prince Charles Point, Isle of Skye, comprises both sauropod and theropod footprints within the Kilmaluag Formation's rippled sandstones. In both cases, the larger sauropod footprints were previously interpreted as different sedimentary structures. On Muck, these cast-infilled features were described as 'spectacular load casts'. Cast asymmetry in cross-section, deformation propagation through underlying coarse-grained beds, and oval to subtriangular shapes in plane view demonstrate these features are dinosaur footprints. At Prince Charles Point, a series of shallow depressions were interpreted as fish resting traces. The presence of crescent-shaped manus traces associated with these oval to circular impressions instead indicates a narrow-gauge sauropod trackway. These recent finds illustrate that, even as ichnologists embrace emerging technologies, the value of revisiting older lithologic descriptions with eyes attuned to the patterns of vertebrate traces cannot be overstated.



## ROAMING IN THE DARK: THE ICHNOLOGICAL RECORD OF THE PEPETXO X CAVE (BASQUE COUNTRY)

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### Keywords

Traces, Quaternary, Bear, Bat, Iberian Peninsula

Although it is relatively common to find ichnological remains within the European caves, this kind of record is generally overshadowed by other archaeo-paleontological findings. Here, we report the abundant record of vertebrate traces, impressed by bears and bats, from the Pepetxo X cave (Amoroto, Bizkaia). Pepetxo X was discovered by the ADES Espeleología Elkartea, who noticed the presence of a human cranium and bear traces. This record still has not a chronological framework. The traces are preserved on the corridors and walls of the cave as autopodial tracks and claw scratches. Autopodial tracks are pentadactyl, measure approximately 15 cm in length and 10 cm in width, and preserve claw traces and both digital and paw pad impressions. The biggest scratch impressions are longitudinal grooves that varies from 2 cm to more than 20 cm long, 1 cm wide, 1-3 cm deep, and have a flat bottom. These traces were probably made by bears while they crossed into the cave by leaning on and climbing the wall. On the other hand, the walls are covered by very fine shallow scratches (less than 1 mm) and about 2-5 cm in length. Two sets of 5 scratches each were also found, with a "v" arrangement between the sets. This kind of traces are generally related to bats and produced by their posterior autopods. The Pepetxo cave presents a very interesting ichnological record with which to delve into the paleoecology and paleobiology of the communities that inhabit the caves.





## STRAIGHT TOES AND CURVY FOOTPRINTS: HOW TRACK MORPHOLOGY CAN DEFORM DURING FORMATION TO DISTORT FOOT ANATOMY

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### Keywords

Dinosaur, Footprint, Track, Simulation



We investigated how curved toe impressions in small bird and non-avian theropod dinosaur tracks can reveal foot movement patterns, rather than foot morphology. Small extant bird and fossil theropod dinosaur tracks can sometimes exhibit curved outer toe impressions (digits II and IV) that may bend either towards or away from the central digit impression (digit III). However, as has been previously demonstrated, “footprints are not feet”: morphology of tracks is not necessarily homologous to trackmaker’s feet. Rather than a 1:1 print, track morphology is the result of a complex foot-sediment interaction. In particularly soft substrates this interaction involves flow and reorganisation of sediment round the moving foot. We experimentally show using Guineafowl that these curved digit impressions can be the result of straight toed feet indenting a soft substrate. Rather than a record of anatomy, the curvature of these toe impressions might elucidate the way in which the foot that made them was moving, and thus be indicative of particular locomotor patterns. To explore this, we used the discrete element method to simulate track formation. Using basic tridactyl feet comprised of four cylinders (three toes and a metatarsus), we generated virtual tracks in a range of abstracted scenarios including toes held at different angles (II–IV interdigital angles of 45 degrees and 90 degrees), toes closing or spreading during indentation, and movement of the foot from vertical, to indenting with forward or backward motions. We demonstrate that curved digit impressions in tracks arise from the flow of sediment around the toes, and the degree of curvature is primarily determined by the functional size of the hypex.



## FOOPRINTS COMPARABLE TO *ROEPICHNUS* AT THE PEHUEN CO PALEOICHOLOGICAL SITE (LATE PLEISTOCENE), BUENOS AIRES PROVINCE, ARGENTINA

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### Keywords

Pehuen Co, Pleistocene, Bird tracks, *Roepichnus*



Diverse bird tracks have been well documented at the Pehuen Co Paleolithic Site (YPPC), Buenos Aires Province, Argentina, including those assigned to the ichnospecies *Phoenicopterichnum pehuencoensis*, *Charadriipeda* isp., *Gruipeda* isp. and *Aramayoichnus rheae*. A relatively recent find at the YPPC indicates the presence of bird tracks with three digit impressions arranged in a trackway composed of four footprints. These footprints are on average of 14.5 cm long and 12 cm wide, and show an incipient trace of webbing. The central digit (III) imprint is longer than the rest, and exceeds the impression of the web, while the lateral digits are shorter, usually curved towards the front of the track, and form an interdigital angle (II-V) of  $\sim 80^\circ$ . The above characteristics largely conform to the ichnotaxobases defined for the ichnogenus *Roepichnus* although the footprints from the YPPC are slightly smaller in size. Despite the fact that *Roepichnus* was defined from tetradactyl footprints, the hallux impression is not always preserved and consequently, occasionally only the impression of three digits can be observed. Therefore, the morphological characteristics of the four YPPC prints are very similar to those of *Roepichnus*, indicating that they belong to this ichnotaxon. The morphological characteristics and sizes of the studied footprints suggest a group of Anseriformes birds of the Anatidae family belonging to the genus *Cygnus* as possible producers.



## NEW DINOSAUR TRACKS FROM THE MIDDLE ALBIAN OF CASCAIS, PORTUGAL (LUSITANIAN BASIN)

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### Keywords

Ornithopoda, Sauropoda, Theropoda, prints, carbonate coastal palaeoenvironment



We describe new dinosaur tracks from the Ponta da Pedra do Sal (São Pedro do Estoril, municipality of Cascais) in the Lusitanian Basin, Portugal. The Ponta da Pedra do Sal tracksite is part of a 11 m thick succession (middle Albian), mainly composed of compact fossiliferous limestone beds, which correspond to the basal interval of the Água Doce Member (Galé Formation). In Cascais, another tracksite (Praia da Parede) was previously described in this same lithostratigraphic unit, but in layers ascribed to the upper Albian. The tracksite is located on the surface of a marly limestone bed, at the upper portion of this exposed succession at the Pedra do Sal promontory. In conjunction with the tracks, the upper bed also contains fragmentary remains of *Nerinea*, a gastropod common in lagoon environments. Each track shows displacement rim, resulting from the expansion of the plastic marly mud due to the pressure exerted by dinosaur weight. Three sets of isolated tracks, without forming any trackway, have been identified: 1 - three ornithopod tracks (one pes and two manus); 2 - four sauropod tracks (two pes and two manus); 3 - two theropod tracks, one of them is a cast that is within a sauropod track of set 2. Altogether, those tracks are assigned to Ornithopoda isp. indet., Sauropoda isp. indet. and Theropoda isp. indet., respectively. In comparison to the Praia da Parede tracksite bearing only sauropod tracks, Ponta da Pedra do Sal reveals a higher dinosaur ichnodiversity in the area, during the Albian.



## IDENTIFICATION OF LARGE ORNITHOPOD MANUS TRACK CASTS FROM THE LOWER CRETACEOUS OF THE IBERIAN PENINSULA

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### Keywords

Peñagolosa sub-basin, Maestrazgo Basin, early Barremian, Ichnology, Styracosterna



Large styracosternan ornithopods could walk quadrupedally although manus tracks are not frequently reported. Generally, manus tracks range in shape from crescent to subrectangular/suboval. Several taphonomic and palaeobiological factors may have influenced the production and registration of such tracks, among others. Despite pes tracks of large ornithopods are common in the Lower Cretaceous Barremian sediments of the Maestrazgo Basin, manus tracks are less reported. It is noteworthy that, at present, the only known manus are preserved as casts. In order to be able to recognize these tracks, it is essential to have appropriate examples, as is the case of a well-preserved manus-pes set from the lower Barremian Camarillas Formation of the Peñagolosa sub-basin, in the municipality of El Castellar (province of Teruel, Spain). Considering its shape, new several manus casts have been identified. They are usually subrectangular, and one of them also exhibit striae, as consequence of the movement of the manus within the substrate. Besides, depending on the depth of penetration (thickness in the case of casts), they can exhibit the impression of the lateral (I and V) and central (II, III, and IV) digits, and that of a convex proximal surface. This type of tracks may be unnoticed, but they are likely to be more abundant than initially expected in the same level and/or tracksite where pes are registered. The morphology can be differentiated from those of other manus tracks of coeval quadrupedal dinosaurs such as sauropods and ankylosaurs.



## DIVING INTO THE PAST: BODY IMPRESSIONS AND SWIM TRAILS FROM SOUTH AFRICA ELUCIDATE RHINESUCHID LOCOMOTORY BEHAVIOUR

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### Keywords

Late Permian, Karoo Basin, Ecca Group, temnospondyl, Ecca-Beaufort contact



Rhinesuchid temnospondyl amphibians were the dominant predators in most non-marine aquatic ecosystems from the Carboniferous to the Middle Triassic. The large, crocodile-like rhinesuchids are relatively well represented by body fossils in Permian aged rocks of the Beaufort Group in the main Karoo Basin of South Africa, but trace fossils attributed to the group are scarce and inferences about their behaviour have relied on skeletal morphology and histological data. Using high-resolution three-dimensional surface scans and aerial orthophotographs, we provide the first comprehensive description of the Lopingian aged Dave Green palaeosurface. The palaeosurface is situated in the uppermost Waterford Formation of the Ecca Group in KwaZulu-Natal Province, South Africa, and is interpreted as representing a sandy tidal flat or floor of a shallow embayment or lagoon along the shoreline of the Ecca Sea. The surface preserves numerous ichnofossils, including tetrapod footprints and fish swim-trails. The most striking ichnofossils, however, are seven body impressions and associated swim trails that are attributed to a medium-sized (1.9 m long) rhinesuchid temnospondyl and provide valuable insight into their behaviour. The preserved traces provide evidence for active swimming and bottom-walking behaviour in rhinesuchids, and support interpretations that they swam using an undulatory motion of the tail with their legs tucked in next to the body, in a manner similar to extant crocodiles.



## A NEW TRACKSITE FROM THE UPPER EOCENE OF THE JACA BASIN (SPAIN): NEW INSIGHTS INTO THE EARLY MAMMAL ICHNOLOGY

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### Keywords

Liédena sandstone, Mammal, Ichnites, Perissodactyl, Artiodactyl



The new ichnological site, named Río Regal, has been recently found in Ruesta (Zaragoza, Spain). Geologically, it is located in the Liédena Sandstone (Guenduláin Formation, Jaca Basin), which has been dated as Upper Eocene (Priabonian) and interpreted as a transitional unit. The ichnites are located on the top of four different, fine-grained sandstone levels with other sedimentary structures, such as ripple marks and wrinkle marks. Three different track morphotypes have been identified. The first morphotype represents small sized didactyl artiodactyl ichnites showing isolated digits with an acuminate anterior margin and a wider and rounded posterior part. This morphotype resembles the ichnogenera *Gambapes* and *Pecoripeda* tracks. The second morphotype is also composed of didactyl footprints, larger in size, with the digits united antero-posteriorly and more deeply impressed into the substrate. It is reminiscent to *Anoplotheriipus* tracks. Both morphotypes were produced by indeterminate artiodactyls. The third morphotype are tridactyl footprints with a larger central digit, lateral digits with similar size and a poorly developed “heel”. These tracks are similar to *Paleotheriipus* and *Plagiolophustipus* tracks and may have been produced by a medium-size member of the family Palaeotheridae. This new ichnoassemblage represents the first evidence of mammal tracks in the Liédena Sandstone where only bird tracks have been previously described. Moreover, it is one of the few vertebrate track records in the Eocene of the Iberian Peninsula, where tracksites of this age are rare.



## NEW VERTEBRATE TRACK RECORD FROM THE YACORAITE FORMATION (MAASTRICHTIAN-DANIAN), ALFARCITO AREA, JUJUY PROVINCE, ARGENTINA

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### Keywords

Vertebrate Tracksite, Littoral Paleoenvironment, Yacoraite Formation, Late Cretaceous, Gondwana

In this contribution, a new ichnological record is presented from the Maastrichtian-Danian Yacoraite Formation (Balbuena subgroup; Salta Group) in the area of Alfarquito (Tres Cruces sub-basin, Jujuy province, NW Argentina). The Yacoraite Formation includes mixed carbonate and siliciclastic deposits sedimented in a shallow epeiric, restricted and tide-dominated sea and that were referred to different sub-palaeoenvironments and associated suites. Two isolated dinosaur footprints were identified on the top surface of a grayish limestone displaying wrinkle and probable peete structures, both originated by biological activity. The first footprint lacks a clear morphology. The second footprint is tridactyl, wider than long (30 cm and 28 cm, respectively), characterized by broad digit imprints, not displaying claw traces, and a wide metatarso-phalangeal area. Footprints were formed by producers roaming on a low-moisture and soft substrate and most likely trampling on microbial mats during their drying out caused by receding tide. The better detailed footprint is here classified as Iguanodontipodidae indet. It shares a similar morphology with others found at the same unit and related to the ichnogenus *Hadrosauropodus*, which is commonly attributed to producers to be sought among Hadrosauridae. The new track-bearing site increases the ichnofauna from the Yacoraite Formation and the record of these kinds of tracks from Gondwana.





## FROM GRAINS TO TRACKS: THE ROLE OF SUBSTRATE ON THE ANATOMICAL FIDELITY OF DINOSAUR TRACKS (UPPER STORMBERG GROUP, SOUTHERN AFRICA)

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### Keywords

Dinosaur Tracks, High-Resolution Sedimentology, Petrography, Track Anatomical Fidelity, Upper Stormberg Group



Tracks result from the interaction between the animal's foot and the sediment properties in which the tracks are registered. The track morphology is strongly controlled by the substrate e.g., tracks registered in saturated versus under-saturated sediments would typically have low- and high-anatomical fidelity (or morphological quality), respectively. The upper Stormberg Group in the main Karoo Basin of southern Africa is rich in Late Triassic–Early Jurassic dinosaur tracks that show variable anatomical fidelity within and between ichnosites. To quantify the role of substrate in the track anatomical fidelity and preservation potential, we examined the petrographic properties (e.g., grain size, grain shape, composition) of the sedimentary host rocks to complement the established macro-sedimentary geology at selected ichnosites. Our results show that: 1. very fine-grained sandstones preserve tracks with higher anatomical fidelity than coarser-grained sandstones; 2. track abundance is higher in fine-grained sandstones; 3. ichnosites preserving microbially-induced sedimentary structures (MISS) are associated with tracks of higher anatomical fidelity, and 4. grain size decreases and roundness increases up stratigraphy. This suggests that the observed increase in track abundance and anatomical fidelity up-stratigraphy, may be related to these micro-sedimentary host rock properties which were ultimately controlled by large-scale changes in the palaeoenvironment from meandering fluvial to aeolian-lacustrine. However, increases in dinosaur populations, and therefore trackmakers, after the end-Triassic extinction events must also be considered.



## CO-OCCURRENCE OF *HYLOIDICHNUS* TRACKS AND MORADISAURINE SKELETONS IN THE PERMIAN OF MALLORCA (W MEDITERRANEAN)

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### Keywords

Ichtnology, Track-Trackmaker Correlation, Locomotion, Functional Prevalence, Captorhinomorpha

In recent years, late Palaeozoic–early Mesozoic track-trackmaker correlation has been bolstered by an increasing amount of tetrapod fossil localities, including skeletons and ichnofossils, and the use of techniques such as photogrammetry. Here, we present the case of the Permian of Mallorca, composed of alluvial red-beds containing both tetrapod skeletons and footprints. Our study is based on the particularly abundant fossils attributed to captorhinomorph reptiles, which include: (1) four skeletons (two sub-adults — one almost complete —, and two juveniles) of a moradisaurine captorhinid, and (2) several isolated manus-pes sets and a trackway of *Hyloidichnus bifurcatus*. The almost complete skeleton represents a medium-sized taxon with a nearly complete left pes that matches almost exactly in size and morphology the pes imprints of *H. bifurcatus* from nearby beds. The trackway shows a partial overstepping of the pes to the manus, with both imprints almost parallel to the midline, and a slightly sinuous tail trace. The calculated glenoacetabular distance is within the range measured in the moradisaurine skeleton (considering spine bending), and the trackway pattern suggests a rather fast locomotion, with hands and feet positioned close to the mid-sagittal plane, implying a relatively upright posture. Slightly different relative depth patterns between manus-pes sets in other *H. bifurcatus* specimens from Mallorca without overstepping and larger in size suggest differences in body mass distribution linked to locomotion and body size. Our study confirms that moradisaurines were among the producers of *Hyloidichnus*, broadly correlated to captorhinomorphs in synapomorphy-based studies, indicating conserved autopodial morphology in the group.





## TEMNOSPONDYL DRAG TRACES: LOCOMOTION STYLES, TAPHONOMY AND PALAEOENVIRONMENTS

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### Keywords

Ichnology, Functional Prevalence, Preservation, Palaeoecology, Permian



Temnospondyls were a group of early tetrapods notoriously abundant in late Palaeozoic–early Mesozoic terrestrial ecosystems, mainly in aquatic environments. Their extensive skeletal record is complemented by an abundant ichnological record. The diversity of track morphologies and trackway patterns indicates a wide array of locomotion styles in temnospondyls. Here we investigate purportedly subaquatic trackways in order to shed light on the locomotion of temnospondyls at a broader scale. This study is primarily based on a trackway from the Cisuralian of the French Lodève Basin including continuous drag traces of the digit tips and the tail. Other similar Cisuralian trackways from France, Spain and USA are analysed and compared with trackways produced in subaerial conditions by temnospondyls. Preliminary data suggest that the manus was more deeply impressed than the pes, possibly linked to a centre of mass of the body located anteriorly. In subaquatic trackways, likely resulting from a bottom-walking gait, limbs performed an alternating arched movement, and the body trunk (partially supported by the water column) aided locomotion through undulatory movements (as the curved digit tip drag traces and the sinuous tail drag trace suggest). The presence of mud-cracks on some specimens indicates periods of desiccation and relatively shallow waters, whereas invertebrate traces were formed underwater; in summary showing dynamic environments, consistent with the interpretation of the trackways. We explore how the different substrate conditions, which are an important factor in the locomotion style, might also impact on the morphology of the trackways from a taphonomic perspective.



## A NEW NON-AVIAN DINOSAUR SWIMMING TRACKSITE FROM THE LOWER CRETACEOUS OF LA RIOJA, SPAIN

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### Keywords

Lower Cretaceous, Ichnology, Dinosaurs, Swimming Behaviour

The discussion about swimming ability of non-avian dinosaurs has increased in recent years in light of new ichnological discoveries and approaches. A newly discovered tracksite from the Lower Cretaceous of La Rioja, Spain, reveals 27 natural casts with non-avian swimming evidences. They show different morphologies, from elongated digit impressions to partial impressions of the distal parts of the pes, with lengths ranging from 8.5 to 29.2 cm and widths from 9.2 to 18.2 cm. Their heterogeneity has led to their classification into 6 morphotypes, according to their features, and into 5 different categories according to the possible sediment-pes interactions that occurred in their formation. Geologically, the tracksite is located in the Lower Cretaceous Urbión Group, composed of mainly sandstone and siltstone levels of fluvial origin. The original footprints were presumably produced in a shallow water fluvial or fluvial-related environment, where the producers were partially or completely buoyant. The different features observed in the natural casts, including linear millimetric striations (scale scratch marks), elongated and not convergent digital impressions, and some natural casts exhibiting complex pes movements suggest that different morphologies are more related to different pes-sediment interactions rather than to different pes morphologies itself. This underscores the challenges inherent in studying swimming tracks, as they can exhibit significant variability even within the same trackway. For this reason, the classification and study approach of these kind of traces, from the pes-sediment interaction perspective, can be a good guiding principle to avoid the ichnotaxonomical problematics that could be raised in their study.





## 'MATALASCAÑAS TRAMPLED SURFACE' FROM THE PLEISTOCENE OF HUELVA (SW SPAIN): HUMAN FOOTPRINTS VS PSEUDOFootPRINTS

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### Keywords

Human footprints, Pseudofootprints, Pleistocene, Matalascañas



The 'Matalascañas Trampled Surface' (MTS) is an exceptional Pleistocene tracksite, bearing terrestrial vertebrate tracks and trackways, invertebrate traces and rhizoliths, and exposed at the El Asperillo coastal cliff base (Matalascañas, Huelva, SW Spain). The MTS is interpreted as a hydromorphic paleosol with abundant rhizoliths developed during the last interglacial period, in a temporarily exposed interdunal area. The vertebrate ichnological suite is attributed to a shorebird ichnofacies and composed by the ichnospecies: *Proboscipeda panfamilia*, *Bovininus uripeda*, *Cervipeda/Bifidipes*, *Suidichnus galani*, *Canipeda* isp., *Presbyorniformipes* isp. and, exceptionally, *Hominipes* isp. (related to *Homo neanderthalensis* by the occurrence in the MTS of Mousterian lithics). Nowadays, the MTS is located in a coastal intertidal area and has the particularity of being almost always covered by the sand of the beach; only during certain storms of the year it can be partially exposed, being then at the expense of intense coastal abrasion. No doubt human footprints with unambiguous anatomical definition have been found in the MTS. However, many of the described 'human footprints' very likely correspond to numerous examples of pseudofootprints (*i.e.*, pits) produced by abrasion upon the friable MTS. Currently and once exposed, the strong erosion suffered by the sedimentary heterogeneities (such as tracks, rhizoliths, desiccation cracks and/or structural fractures) present at the MTS, has resulted in pseudofootprints, which commonly exhibit elongated shapes, abrasion pits with the (bio)clasts that promoted them, lack of typical foot morphological features or sediment displacement rims, and preferential SW-NE orientations that are perpendicular to the current coastline.



## BRINGING DINOSAUR TRACKMAKER BEHAVIOUR TO LIFE: 3D MODELLING AND ANIMATION TECHNIQUES USING LARK QUARRY AS A CASE STUDY

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### Keywords

Dinosaur, Trackways, Trackmaker, 3D modelling, Animations



Traditionally, the study of dinosaur trackways has relied mainly on text- and figure-based descriptions of trackmaker behaviour. However, this approach has limitations regarding accessibility and understanding, particularly for the broader scientific community and the public. In this contribution, we propose a new method of studying dinosaur trackways using 3D modelling and animation techniques to bring trackmaker behaviour to life. By harnessing the potential of visual media, the current approach enables researchers to generate realistic and detailed representations of trackmaker behaviour, improving the impact and reach of their research and contributing to the advancement of scientific understanding. Our method uses Lark Quarry as a showcase, utilising comprehensive data sets including a complete map of the tracksite, spatial positions of trackways, and footprint and stride length data. We then reconstruct virtual dinosaur trackmakers within the trackways, resulting in a more intuitive and accessible representation of dinosaur behaviour and locomotion. Additionally, the decreasing cost and increasing popularity of 3D modelling and animation techniques make this approach more accessible to researchers in the field.



## THE LAVINI DI MARCO TRACKSITE: A REVIEW OF THE QUADRUPEDAL TRACKWAYS AND THEIR PALEOBIOGEOGRAPHICAL SIGNIFICANCE

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### Keywords

Early Jurassic, Trento carbonate Platform, dinosaur tracks, Photogrammetry, Sauropodomorpha

The Lavini di Marco ichnosite is located near Rovereto (Trentino-Alto Adige, NE Italy), on the western slope of Mt. Zugna. The track-bearing layers are referred to the Monte Zugna Fm. (Hettangian-lower Sinemurian) of the Calcarei Grigi Group, settled down within the palaeogeographic domain of the Trento carbonate Platform. The ichnological survey was carried out using traditional methods (*i.e.*, ichnological fieldwork), and aerial and close-range photogrammetry. More than seventy 3D models, of both bipedal and quadrupedal tracks were produced by means of aerial and close-range photogrammetry. These models were analysed using of color-coded and contour line images, allowing to improve interpretations based on fieldwork. The 3D models of the best-preserved tracks were used for the osteological reconstruction of the trackmaker autopodia, assuming an arthral position of the phalangeal pads. three indirect methods were used to correlate the tracks and their trackmakers: (i) synapomorphy-based approach; (ii) phenetic correlation; (iii) coincidence correlation. These methods were used in combination with morphometric parameters, both to identify affinities and to exclude incompatible taxa. The ichnotaxonomical analysis resulted in the emendation of the diagnosis of *Lavinipes cheminii* and the assignment to *L. cheminii* of several other sparse tracks and trackways, previously not assigned to any ichnotaxa. The reconstruction of *L. cheminii* trackmaker fore- and hind-limbs supports a possible attribution of the traces to the sauropodomorph *Gongxianosaurus shibeiensis*. This attribution corroborates a possible Laurasian affinity for the Lavini di Marco dinosaur assemblage, in contrast with previous assumptions that linked the Southern Alps palaeogeographic domain with the Gondwana mainland.





## DIDACTIC VISUALS OF TRACE FOSSILS AS AN EXTENSION OF PALEOART

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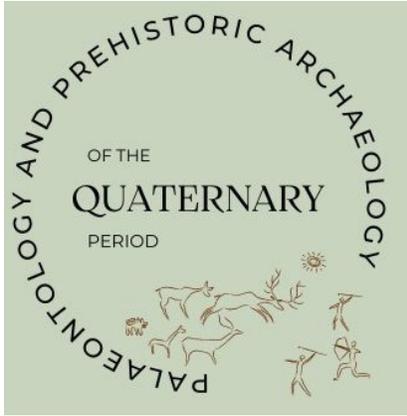
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### Keywords

Ichnology, Popularization, Scientific Communication, Scientific Illustrations



Didactic visuals are important in translating ichnology to the general public, specifically herein dinosaur trace fossils. Illustrations serve as valuable tools in scientific communication and teaching aid resources to popularize research data. It can be challenging to present ichnology to a wider audience in a scientifically accurate manner because some aspects of the extinct organisms that have left these traces remain unknown and direct observation is not possible. In this study, we utilized the trace fossil collection and associated data from the PAL A16 collection, housed at the JURASSICA Museum, in the Jura of Switzerland. This collection includes fossil tracks and casts of sauropods and theropod dinosaurs as well as their associated track and trackway measurements obtained during fieldwork. This collection of scientific material needs to be simplified and translated for a lay audience. This was done by designing generalized approaches to deal with different datasets (i.e., from a track to a measurement of a track). Additionally, educational activities have been designed to incorporate ichnological principles. These materials are generated in order to be (i) attractive to the general public and (ii) to explain the scientific data from the Jurassica Museum collection in an easily digestible way. This makes these intriguing track collections available not only to scientists but also a more general audience. The methods used in this study can be applied to any collection or other scientific data, which could potentially simplify the communication of science news to a wider audience, and draw more people to public natural science facilities.



The Quaternary, the last of the Earth's geological eras, is characterised by the alternation of temperate and glacial periods and by the development of the genus *Homo* and its global expansion. A changing climate and the constant advance or retreat of different ecosystems, as well as the relative abundance of their material remains, in comparison with other geological periods, make the research of this period particularly interesting.

Although the research related to the evolution of our genus is well known, the study and analysis of the fossils of the species that coexisted with

our ancestors can provide us several data not only on the environment they inhabited and the fauna they lived with, but also on their habits, diets and even their social, economic, cultural and even technological evolution.

The palaeontological analysis of the Quaternary records, focused on the taxa and species represented, is complemented by taphonomic analysis, aimed at finding out what actions were carried out on the bones and therefore inferring certain hunting or social behaviours.

For this reason, the importance of developing a session focused on the Quaternary is not only centred on palaeontological aspects, but also on paleobiologic and behavioural contents.

This session is open to all studies focused on the archaeopaleontological research of the Quaternary period. Some of the topics covered in this session are the following:

- Faunistic studies focused on morphometric features.
- Ecological approaches of the Quaternary period.
- Formation of different fossil deposits, as well as other types of research with taphonomic implications.
- Contributions of Palaeontology to Prehistoric Archaeology in any of its aspects.

# Palaeontology and Prehistoric Archaeology of the Quaternary Period

## Organisers

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## Thematic Session





## **CAPRA PYRENAICA DEPOSITS IN THE MAGDALENIAN PYRENEES. A POSSIBLE RITUAL BEHAVIOUR IN THE NIAUX AND BÉDEILHAC CAVES (ARIÈGE, FRANCE)**

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### **Keywords**

Niaux, Bédeilhac, Magdalenian, Capra pyrenaica, Ritual behaviour

The caves of Niaux and Bédeilhac (Ariège, France) are known for their relevant Magdalenian artistic records. Nevertheless, few research have focused on the fossil remains identified in both caves. In this study, we present four deposits with fossil remains of *Capra pyrenaica*. All of them consisting of limb bones, which are located in specific sites far from transit areas. In Niaux cave, the remains of the “Diverticule du Bouquetin”, the “Locus des humérus” and the “Locus de l’astragale” have been analysed. These fossils show little or no primary displacement together with marks and fractures compatible with anthropic action. In Bédeilhac cave, several limb bones have been identified in the “Galerie des Modelages”. Its location and the morphology of the site reject a natural deposit or a deposit by small mammals. These deposits are found in areas close to the entrance of the caves, but in places of complete darkness and far from the habitat and transit areas. Their location reveals a site selection. The dates obtained allow us to associate them temporally. The analysis of these *Capra* remains and their location in both cavities allows us to propose a possible Magdalenian ritual activity.





## COMPARATIVE 3D GEOMETRIC MORPHOMETRIC ANALYSIS OF THE PROXIMAL HUMERUS OF SUBFOSSIL LEMURS OF MADAGASCAR

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### Keywords

Locomotor And Postural Behavior, Functional Morphology, Convergence, Hominoids, Glenohumeral Joint

The subfossil lemurs of Madagascar are recently extinct (~10K ya) large-bodied lemurs, which exhibit morphological convergences with hominoids in the wrist and elbow, as well as with groups well outside primates, such as koalas (e.g., *Megaladapis*) and sloths (e.g., *Paleopropithecus*). Subfossil lemurs also share with hominoids and these non-primate groups the use of suspensory locomotor and postural behaviors. Here we use 3D geometric morphometrics to comparatively assess the morphological affinities of the proximal humerus of five specimens of extinct subfossil lemurs (*Megaladapis* and *Mesopropithecus*) with 11 primate genera (including hominoids, cercopithecoids and platyrrhines) and one stem hominoid (KNM-MB 21206, *Nyanzapithecus*) as a means to characterize their locomotor and postural behaviors. Results show clear-cut differences between hominoids + *Ateles* in contrast to the rest of the analyzed taxa, reflecting both differences in locomotor behaviors (suspensory vs. arboreal quadrupedal locomotion) and body plan organization. All five subfossil lemurs display morphological affinities with the large non-suspensory platyrrhines (*Alouatta*), cercopithecoids (e.g., *Colobus*, *Macaca*) and the nyanzapithecine by displaying humeri with protruding tubercles above the articular surface. This suggests that *Megaladapis* and *Mesopropithecus* were mainly pronogrades in posture, despite using their arms in hanging/suspensory positions. Thus, they might have not entailed the same functional requirements regarding mobility and full glenohumeral circumduction as suspensory hominoids.

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## A NEW LOOK AT OLD BONES: REVISING THE MAMMALIAN FAUNA FROM THE CALABRIAN SITE OF 'UBEIDIYA, ISRAEL

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### Keywords

Levant, Calabrian, Mammals



'Ubeidiya, Israel, has been a focal site for the study of Levantine Quaternary fauna. A series of excavations were conducted from 1960 to 1999, and in 2021-2022. The site exhibits Acheulean lithic and rich vertebrate fossil assemblages. Since the publication of "Les mammifères du pléistocène inférieur de la Vallée du Jourdain à Oubeidiyeh" in 1986 and others in the early 2000s there have been many changes in our understanding of mammalian taxonomy, new comparative material has been uncovered, and new analytical methods have been developed. In addition, new faunal material has been recovered in the new excavation and from older collections. Here we present preliminary results from a revision of the 'Ubeidiya mammalian fauna with a focus on updated taxonomy, taphonomy, modern analogue technique and ecometrics. Results suggests that the identification of some species (*e.g.*, *Parapodemus jordanicus*) could not be sustained while other new species have been uncovered (*e.g.*, cf. *Homotherium*, *Cricetus nanus*) The number of endemic species, which was a hallmark of previous studies, is greatly decreased. While the fauna of 'Ubeidiya includes elements from different zoogeographic regions, the high relative proportion of African taxa is now reduced. The newly revised biochronology for the sequence is consistent with the earliest Biharian corresponding to the later phases of Odessian small-mammal assemblage, which suggests a date between 1.5-1.8 Ma, older than previously estimated based on large and small mammals and which contributed to the discussion on the date of the earliest dispersal of the Acheulean out of Africa.



## CARNIVORE REMAINS FROM CASTILLEJO DEL BONETE (TERRINCHES, CIUDAD REAL)

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### Keywords

Chalcolithic, Bronze Age, *Meles meles*, *Canis lupus familiaris*

Castillejo del Bonete (Terrinches, Ciudad Real, Spain) is an archaeological site located on the southern edge of the Iberian Plateau, to the north of the Sierra Morena mountain range. This site was a funerary place used between 4416 and 3515 years cal. BP according to radiocarbon dating on charcoal and human bones. It is a Chalcolithic-Bronze Age structure composed of a cave monumentalized with corridors and tumuli associated with funerary remains and votive deposits. The record of this site consists of bone remains, pottery, lithic and bone industry. The faunal assemblage is mainly comprised of domestic (*Ovis aries*, *Capra hircus*, *Bos taurus*, *Sus domesticus* and *Canis lupus familiaris*) and wild fauna (*Cervus elaphus*, *Oryctolagus cuniculus* and *Meles meles*). Here, we analyse the carnivore sample from Castillejo del Bonete. The assemblage includes 29 remains, of which 16 (MNI=4) have been identified as domestic dogs. The dogs' sample principally consists of fragmentary hemimandibles and maxilas, but also includes postcranial remains (tibia and metapodial bones). We compare it with modern dogs and wolves and metrics analyses indicate that these fossils are smaller than modern sample. Two remains show cut marks, so consumption cannot be discarded. The other 13 remains (MNI=2) are attributed to the European badger based on morphometric studies. The badgers' sample consists of postcranial (humerus, phalanges, metapodial bones) and cranial remains. Metric analyses fall within the average range of the Iberian badgers' population. The presence of this animal could indicate that, at that moment, the cave was no longer used as a burial site.





## LOWER PALAEOOLITHIC TURTLE REMAINS IN THE IBERIAN PENINSULA ARCHAEOLOGICAL RECORD: AN UPDATE

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### Keywords

Archaeozoology, Upper Pleistocene, *Chersine hermanni*, *Mauremys leprosa*, *Emys orbicularis*



The study of Testudines remains recovered in archaeological contexts and its relationship with the genus *Homo* is a research topic of growing interest within the scientific community. In the Iberian Peninsula, tortoise remains (*Chersine hermanni/Testudo hermanni*) have provided relevant data concerning its use as a dietary resource by *Homo neanderthalensis*. Framed within a broader discussion regarding the consumption of small prey (e.g., leporids, birds) in pre-Upper Palaeolithic contexts, tortoise role in neanderthal palaeodiet has proved that this behaviour is not exclusive of the anatomically modern humans. In addition, the Quaternary Iberian Peninsula fossil record of the genus *Testudo* has also been assessed, revealing that *Chersine hermanni/Testudo hermanni* almost disappeared from the archaeological record by the end of the Middle Palaeolithic. The reasons of this event have been related to its rarefaction and probable extinction in several areas mainly due to climatic and cultural factors. In contrast, other Iberian chelonian forms, such as terrapins (*Mauremys leprosa* and *Emys orbicularis*), its Quaternary incidence, and its connection with the genus *Homo* from the Lower Palaeolithic onwards have been poorly addressed. To counterbalance this gap, a detailed review of the Iberian Peninsula Lower Palaeolithic (ca. 1.3/1.25 myr – 350 ky BP) turtle archaeological record is here offered. Material data from ten Iberian archaeological sites is examined, three of them being first-hand analysed and hitherto unpublished. Thus, an update of the information regarding Iberian turtle Lower Palaeolithic archaeological record is accomplished. Also, a general retrospective view of Iberian Testudines archaeological Quaternary record is presented.



## ISOTOPIC GLIMPSES FROM THE NAHUEL HUAPI REGION IN THE LAST 20,000 YEARS FROM EXTINCT AND EXTANT SPECIES

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### Keywords

Megafauna, Patagonia, Paleontological and Archaeological Record, Humans



Fifteen new stable isotopic measurements from the Nahuel Huapi region (Patagonia, Argentina) of the last 20,000 years BP are provided. These includes the first isotopic estimates derived for the extinct *Megatherium americanum* and Mylodontidae (Xenarthra) from the Last Glacial Maximum of Patagonia. Also, *Hippocamelus* sp., *Hippocamelus bisculus* and *Lama guanicoe* (Artiodactyla) were measured. The sample was recollected in a paleontological site and two rock shelters (El Trébol and Arroyo Corral) with paleontological and archaeological levels. The particular record of the Nahuel Huapi region allows expanding the range of isotopic studies in Patagonia and South America Southern Cone for this crucial period, providing this type of information in the studied region for the first time. The  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values allow in reconstructing the paleoenvironment between the Late Pleistocene and Holocene, when drastic climatic and biotic events occurred that shaped the modern landscape and faunal communities (e.g., megamammal extinction and the first human dispersal in the Americas). The  $\delta^{13}\text{C}$  signature remains stable along the entire period, only *M. americanum* shows less depleted  $\delta^{13}\text{C}$ . The  $\delta^{15}\text{N}$  signature supports fast Pleistocene-Holocene environmental changes, from glacial (i.e., cold and dry) in the Last Glacial Maximum to warmer and more humid conditions in Post Last Glacial Maximum times. An abrupt West to East gradient is maintained along the 20,000 years BP in this region, being El Trébol moister than Arroyo Corral. Despite these environmental differences, earliest human signs in both sites were dated circa 10,000 BP, related with the first dispersal wave in the Americas.



## THE HYENA AS A TAPHONOMIC AGENT AT THE LAYNA SITE (SORIA, SPAIN) ON THE *GAZELLA BORBONICA* SPECIES

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### Keywords

Pliocene, taphonomy, toothmarks, *Gazella borbonica*, Hyenidae

Layna (Soria, Spain) is a 3.9 Ma (Ruscinian, Lower Pliocene) faunal assemblage known by the fauna of amphibians, reptiles, birds, small mammals, and large mammals (bovids, canids, cervids, equids, felids, hyenas, rhinoceros and ursids). The site deposits as a karst doline fill. Still, the bone accumulation is related to the action of birds of prey and hyenas, even though there were also canids (*Nyctereutes donnezani*), felids (*Caracal depereti*, *Felis* aff. *silvestris*, *Acinonyx* sp.), and ursids (*Ursus minimus*). The hyena's species are *Chasmaporthetes lunensis*, a cursorial hunter with a more carnivorous diet, and *Pliocrocota perrieri*, which processed the bone carcass. To learn more about the hyenas' predation, we developed a taphonomic study on the most consumed prey, the *Gazella borbonica* species, which presents an NR (number of remains) of 1188. The remains correspond mostly to adult individuals (84.7%) and the rest to infantile, juvenile, and senile. The postcranial bones (1046 elements) predominate over the cranial ones (141 elements), and most show a complete anatomical element. The fragmented bones are fully identifiable, with a high survival of the epiphyses, although we found a few diaphyses. A few toothmarks have been identified at the bones' cortical surface: Pits distributed at the large bones-phalanges epiphyses and the metapodials diaphyses; Scores at the central area of the phalanges; Punctures isolated. Nevertheless, there is no presence of furrowing or trampling. Overall, the identified action corresponds more to a meat diet predator due to poor bone processing, similar to the method of the hyena specie *Chasmaporthetes lunensis*.





## THE EXCEPTIONAL RECORD OF A LATE PLEISTOCENE FLAMINGO EGG IN THE BASIN OF MEXICO

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### Keywords

Flamingo, Phoenicopteriformes, Mexico, Pleistocene, fossil egg

The flamingos (Phoenicopteriformes) are a group of neognathous birds with some fossil records in the American continent, such as the United States, Mexico, Costa Rica, Venezuela, Argentina and Uruguay. Their chronology ranges from the Late Miocene to the Late Pleistocene. In Mexico, their records are from the late Cenozoic and are located in the states of Mexico, Jalisco and Puebla. This is evidence that they once inhabited the Trans-Mexican Volcanic Belt, became extinct sometime in the Holocene, and currently inhabit the Yucatan Peninsula and the Caribbean. The record of fossil bird eggs is even rarer, so this one is considered unusual and of great importance. The discovery is located in the town of Santa Lucía, municipality of Zumpango, State of Mexico, Mexico, where the works for the construction of the "Felipe Angeles International Airport" were carried out, where hundreds of fossil specimens have been found, including mainly Columbian mammoths, as well as a variety of vertebrates that occupied the Pleistocene levels of this ancient lake in the Basin of Mexico. The analyzed specimen is practically complete. Based on measurements, shape, eggshell pattern, and comparison with other recent birds, it was identified as a flamingo egg, but without a specific classification. This is the first record of a fossil flamingo egg and adds another locality to the record of this group of birds in the Basin of Mexico, allowing us to discuss biogeographic and paleoenvironmental implications about the Santa Lucía locality in the past.





## THE LOWER GALLERY OF LA GARMA (SPAIN): THE FORMATION OF AN ARCHAEOPALAEOLOGICAL CAVE CONTEXT SHARED BY CARNIVORES AND HUMANS DURING THE UPPER PALAEOOLITHIC

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### Keywords

Hominin-Carnivore Interaction, Ursids, Palimpsest, late Pleistocene

Carnivores play a significant role in the formation of palaeontological and stratigraphical contexts. Additionally, due to the alternative use of caves between carnivores and humans, they contribute in many ways to the formation of archaeological sequences too. The behaviors exhibited by carnivores inside caves can be viewed from an archaeological perspective as either disruptive or constructive. In turn, human activities can also impact palaeontological contexts in similar ways. Therefore, understanding and characterizing the role of carnivores in anthropic cave contexts is a valuable contribution to the fields of archaeology and palaeontology. In this study, we present the results obtained from the karstic system of the Lower Gallery of La Garma, which preserves exceptional evidence of both human and carnivore activities during the Upper Late Pleistocene. The well-preserved palaeofloors in this site, which have not been altered by post-depositional processes, have allowed us to identify and characterize the behaviors of each agent and their interrelationships. Our findings are relevant to understanding the formation processes of archaeopalaeontological contexts.





## A ZOOARCHAEOLOGICAL APPROACH TO HOUSE A AND B AT NUMANTIA (GARRAY, SORIA, SPAIN)

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### Keywords

Numantia, *Oppidum*, House A and B, Iron Age

This work presents the faunal data from the oppidum of Numantia (Garray, Soria, Spain), particularly the results from two domestic units excavated between 1999 and 2000, House A and B. Both are located in the North sector of the town, using a previous defensive rampart as a constructive terrace. These houses show the typical tripartite building pattern, separating the domestic space into three rooms and outdoor courtyards. After analysing a total of 1,561 faunal remains, the main taxon are the ovicaprids herd in both houses, followed by bovids and pigs. Most of them were adult individuals, although in House B the remains of infant and juvenile animals stand out too. Additionally, we have observed that in House A most remains came from the courtyard, whilst in House B they were recorded in a cobbled area, possibly the pavement of a street. Therefore, the largest concentration of zooarchaeological remains clusters in transit areas. The cut marks have also been examined and are present in all anatomical sections of the three taxa found in both areas. Consequently, the three taxa recorded (*Ovis/Capra*, bovids, and pigs) were used until the end of the animals' service life as labour force, fertilisers, etc. Finally, when no secondary use could be obtained from the animals, they were consumed.





## UNUSUAL PRESENCE OF QUATERNARY ASSOCIATED SKELETONS IN A NEW KARSTIC CAVE OF MALLORCA (SPAIN)

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### Keywords

*Myotragus* sp., *Hypnomys morpheus*, *Tyto alba*, Karst, Cave



Karstic caves are reputed places containing vertebrate fossil accumulations. Usually, fossils are water-transported and bones of different specimens remain mixed. To date, less than ten out of c. 200 cave deposits have delivered associated skeletons of Quaternary vertebrates in the Balearic Islands. Thus, any new site with individualised associated skeletons is relevant to obtain information on the fossil species. Here, we report the discovery of a new locality holding an unusual number of individualised associated skeletons: Cova de ca na Biela (Manacor), a structural collapse cave (80m long, 22m deep) excavated in upper Miocene materials. Fossils were firstly detected during the topographic surveys. Subsequently, in order to avoid their destruction by visitors' trampling, 654 fossil bones scattered among the rocks and flowstone were recovered. This new fossil material includes 197 bones representing 7 specimens (6 of them, uncomplete associated skeletons) of *Myotragus* sp., 216 representing 5 specimens (3 of them, uncomplete associated skeletons) of *Hypnomys morpheus*, and 241 of 6 uncomplete associated skeletons of *Tyto alba*. The analysis of dentition of *Myotragus* sp. points to a Middle-Upper Pleistocene age. The unusual high presence of isolated skeletons scattered across the cave indicates that it acted as a natural trap. The spatial distribution of different skeletons of *T. alba* and *Myotragus* sp. documents the former presence of a currently collapsed entrance.

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## SUID CONSUMPTION THROUGHOUT THE HOLOCENE IN EL PORTALÓN DE CUEVA MAYOR (ATAPUERCA, BURGOS)

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### Keywords

Domestication, Taphonomy, Pig Husbandry, Holocene, Iberian Peninsula

The consumption of domestic pigs is common during the Holocene and an important source of meat in the subsistence strategy of the inhabitants of the Iberian Peninsula. This work presents a detailed zooarchaeological and taphonomic study of suid bone remains from the Neolithic to the Middle Ages of El Portalón de Cueva Mayor archaeological site (Atapuerca, Burgos) to infer possible changes in its management. El Portalón site includes an almost complete and continuous archaeological stratigraphic sequence ranging from Neolithic to Middle Ages. The bone assemblage was recovered from different cultural contexts (domestic, stabling and funerary contexts) and from different cultural levels: Neolithic; Pre-Bell Beaker Chalcolithic and Bell-Beaker Chalcolithic and Early and Middle Bronze Age. Pig constitutes the third domestic taxa more abundant in the subsistence strategy of the inhabitants of El Portalón de Cueva Mayor. Anthropogenic taphonomic evidence, such as cut marks, human tooth marks, dynamic loading, and fire modifications, suggest the consumption of domestic suids through the whole chronocultural sequence. A decrease in pig size and a change of management towards the exploitation of older individuals are observed from the Neolithic to Bronze Age. The possible causes of these changes are analyzed and discussed in this work.





## GEOCHEMICAL IMPRINT OF TERMITES ON OF MIDDLE PLEISTOCENE NEST CARBONATES (CALITZDORP, SOUTH AFRICA)

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### Keywords

Middle Pleistocene, termitaria, geochemistry



Termites are large-scale geo-engineers known for their large, intricate nest structures. During nest building, termites preferentially collect materials from the surrounding soils, changing the local soil chemistry and sediment grain size distribution. Consequently, the geochemistry and grain size composition of a nest reflects the termite colony's behaviour. Neo-ichnological studies have shown that termites preferentially use finer material (fine sands and clays) and a combination of fecal matter and saliva to construct their homes. Therefore, nests are more alkaline and enriched in organic matter relative to the host soil horizon. Here, we investigate the geochemical composition (major and trace elements) of two unique, Middle Pleistocene fossil termitaria near Calitzdorp (South Africa) to better understand the building habits of these ancient termites. The fossil nests are preserved as calcretised structures in calcified sand palaeosols which are overlain by a calcrete hardpan. Our preliminary results indicate that, relative to the host palaeosol, the fossil nests are 1) enriched in calcium and magnesium which may be linked to carbonate precipitation as well as termite activity, 2) enriched in copper and chromium which can be linked to the biogeochemical role of termites and 3) depleted in potassium and aluminium. The depletion in potassium and aluminium is unusual for the fine-grained muds and clays which are usually present in termite nests and thus requires further investigation. To better understand these initial observations, we aim to sample additional fossil nest structures and compare our data to modern, southern African termite nest compositions.



## **EQUUS SIVALENSIS FROM THE PABBI HILLS PLEISTOCENE OF PAKISTAN**

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### **Keywords**

Equidae, Mammalia, Paleontology, Quaternary, Siwalik

The deposits of fossils in the Siwalik Hills of Pakistan are the primary way to understand the diversity and advancement of mammalian evolution. The new equid material has been recovered from the Upper Siwalik Subgroup at Sardhok (Pabbi Hills, Pakistan) and may have an age between 2.6 and 0.6 Ma. The large-sized and relatively hypsodont horses are common elements of the Pleistocene faunas of the Subcontinent. The material comprises maxilla and mandible fragments and isolated teeth. The horse fossils from the Pabbi Hills share the following features with *Equus sivalensis*: protocone fused to the protoloph, the low number of simple plications, caballine fold, long protocones and large size. The large teeth and long protocone of the Siwalik equid may be an adaptation to the niche of a grazer. The study of *E. sivalensis* with the mammalian guild of Sardhok suggests the early Pleistocene age and an open habitat with a well-watered landscape at Sardhok, Pakistan.





## CARNIVORES AND HUMANS DURING THE LATE MIDDLE AND UPPER PALEOLITHIC PERIOD: THE CASE OF EL OLIVO CAVE (LLANERA, ASTURIAS)

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### Keywords

Magdalenian, Subsistence, Biotic interactions, Taphonomy, Zooarchaeology



El Olivo (Llanera, Asturias) is an archaeological assemblage with Magdalenian and Mousterian levels, whose study can be of great interest for the analysis of human occupations in the north of the Iberian Peninsula during the late Middle and Upper Paleolithic. The occupational history of El Olivo is not easily reconstructed because of the alternation between carnivores and humans in the stratigraphic sequence. However, the faunal remains are examined with the aim of determining the nature of the accumulation. The bone assemblage is characterized by a high diversity of ungulates, with *Cervus elaphus* as the most important taxa, followed by *Equus ferus*. Carnivores are less abundant but still represented by diverse species (e.g., *Alopex lagopus* and *Canis lupus*, among others). Human activity is proved due to the presence of cut and percussion marks on the ungulate bones in all levels, but also on *Oryctolagus cuniculus* and bird remains in level 4. On the other hand, high frequencies of tooth marks are observed throughout each level, especially in Level 1, 2, 3, 4 and 7. Through the taphonomic analysis of those remains, it has been possible to approach to the strategies of subsistence of the hunter-gatherers and their interaction with carnivores. In this way, this study shows that the origin of the accumulation varies depending mainly on the size of the animals in each of the levels. Carnivores acted as the main agents in the accumulation of small and large ungulates, while humans would have contributed those of medium size.



## NEANDERTHAL MACRO-MAMMAL EXPLOITATION AND PROCUREMENT STRATEGIES IN GRUTA DA FIGUEIRA BRAVA (PORTUGAL)

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### Keywords

Faunal Remains, Subsistence Strategies, Last Interglacial, Middle Palaeolithic



Gruta da Figueira Brava is located about 30 km south of Lisbon, Portugal, and it has a confirmed MIS 5b-5c occupation. Today, the site faces the sea, but during its Neanderthal occupation the coast was about 2 km away. The macro-mammal assemblage recovered from the most recent excavations is highly fragmented and carbonate-coated. Nonetheless, it was possible to identify the presence of several ungulate species, as well as different carnivores. The latter are mainly represented by coprolites, but the absence of juvenile carnivores and the lack of digested bones, indicate that their use of the cave was only sporadic and whenever humans were not present. Ungulates are mainly represented by two predominant taxa — red deer and ibex — even though other larger ungulates were also consumed, like aurochs and horse. Bone surface modifications, skeletal part analysis, long bone fusion and tooth wear analysis indicate that humans had primary access to their carcasses. Although large prey was not brought whole to the cave, that was not the case for deer and ibex. These were brought as complete animals to the site, where they were processed, and their flesh and marrow consumed. Macro-mammals benefitted from a rich ecotone in the cave's surroundings, which included patches of forest, grassland and shrubland, thus profiting from a permanent herbaceous cover. Therefore, ungulates may have been hunted locally. Considering the age of the animals being targeted, species' feeding behaviour and the resource-rich location of the site (with plenty of other marine and vegetal resources available), it is envisaged a year-round human occupation of the cave, meaning intermittent, not continuous, with visits during all seasons.



## DARWIN'S GROUND SLOTH: TAPHONOMIC ANALYSIS OF THE *SCELIDOTHERIUM LEPTOCEPHALUM* (XENARTHRA, FOLIVORA) HOLOTYPE

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### Keywords

Beagle, Punta Alta, Preservational history, Megafauna, Pleistocene

Charles Darwin made geological and paleontological interpretations in the Bahía Blanca area (Buenos Aires Province, Argentina), during 1832 and 1833. Among the megamammals remains collected in Pleistocene fluvial deposits, from Punta Alta costal cliff, he recovered a nearly complete skeleton that constitutes the holotype of the extinct ground sloth *Scelidotherium leptocephalum*. Darwin made comments on the preservation state of this specimen and made an attempt to reconstruct its taphonomic history. In this contribution, we summarize the taphonomic features of this specimen without considering sullegic and trephic factors and also highlight Darwin's facet as taphonomist. The skeleton, belonging to a juvenile individual, includes most of the skeletal elements (excepts appendicular elements and vertebrae, lost during World War II), articulated to each other and mostly complete. Weathering includes slight splitting in scarce elements. Abrasion is absent. Left hemimandible shows marks (e.g., pits, punctures, furrows, and crenulated edges) linked with predators/scavengers' activity. All these features suggest a relatively short time of subaerial exposition. The presence of invertebrates (e.g., Cirripedia, Polychaeta, and Bryozoa) attached to the remains and traces of Polychaeta affecting their surface indicate that, after the original burial, the skeleton was re-exposed (probably during Holocene) and affected by processes related to a water-sediment interphase in a marine environment. Some of these features were noted by Darwin in his publications, but others (e.g., tooth marks, invertebrate traces) are described for the first time here. The information obtained suggest a complex taphonomic history, which generates the particular interest to Darwin for this specimen.





## THE VEJA CAVE (VERONA, NORTHERN ITALY): NEW INTERDISCIPLINARY FRONT OF RESEARCH

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### Keywords

Late Pleistocene, Cave Deposit, Radiocarbon Dating, Faunal Assemblage

The new investigations at Cave A, in the karst area of the natural arch of Ponte di Veja (Monti Lessini, Verona) was urged by unauthorized excavations that threatened the integrity of the deposit, and it is led by a team from Ca' Foscari University of Venice within the Horizon 2020 project. The 2022 campaign focused on the selection of the areas to be investigated, removing the leftover sediment in the innermost area of the cave (trench 160.01), revealing a stratigraphic record still in its primary deposition. The upper deposit returned lithic artefacts and many fragmented charcoals. The radiocarbon dating on charcoal returned an age of  $10,800 \pm 30$  BP (uncal BP), assigning this stratigraphic unit to the Holocene. More than two hundred fossil remains have been collected from reworked sediments of trench 160.01, primarily attributed to *Ursus spelaeus*, *Canis lupus*, *Meles meles*, bats (genera *Myotis* and *Miniopterus*), rare micromammals teeth, and herpetofauna. The quality of the collagen extracted from two teeth of cave bear for radiocarbon dating (preliminary data), and the presence of this species allow us to refer this fauna to the end of MIS 3. The fossil material is under study to extract stable isotopes and the genetic content. Analyses on soil and charcoal are in progress, to understand the chemical content and the burning conditions. Our goal is to reach a comprehensive reconstruction of the deposit with a multidisciplinary approach, to understand the faunal assets of the area along with human settlements and across the last glaciation.





## MODERN FORAMINIFERA DISTRIBUTION OFFSHORE JERUDONG, BRUNEI DARUSSALAM

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### Keywords

Foraminifera, distribution, Jerudong, offshore, Brunei

Brunei Darussalam is situated in the heart of the Coral Triangle, an area rich in marine biodiversity. Studies on offshore sites in Brunei have recently increased, but no studies have been conducted on the offshore sites of Jerudong. The sites in Jerudong are protected areas associated with a beach and a few cliffs, and they are interconnected with a few river channels. As a result, the area has a mix of fluvial and marine waters, resulting in unique ecosystems. The distribution of foraminifera from five (5) Jerudong offshore sites (Arun Wreck, Bubble Reef, Champion Wreck, Sukun Reef, and Yewli Wreck, with depths ranging from 16 to 20 meters) was studied, and certain moderate depths of water (15.7 meters, 16.9 meters, 17.2 meters, 20 meters, 20.9 meters and 23.8 meters) were chosen to determine foraminifera trend within this affected ecosystem including the symbiont-bearing foraminifera (e.g., Large benthic foraminifera). Our findings identify a total of 60,867 foraminifera individuals from 68 taxa and 316 species, with symbiont-bearing foraminifera genera *Neoassalina*, *Amphistegina*, *Elphidium*, and *Quinqueloculina* being the common genera observed in the shallower waters. Planktonic foraminifera genus *Globigerina* also showed an increasing trend going deeper suggesting a typical shelf to deep marine environment system. According to our results, Jerudong channels and mixed water systems have no immediate effect on suspended sediments and light penetration of Jerudong offshore sites as proven by the foraminifera data collected.





## HUMAN–ANIMAL RELATIONS IN THE PLEISTOCENE: NARRATION AROUND THE WOOLLY RHINOCEROS

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### Keywords

Hominids, Woolly Rhinoceros, Pleistocene, Eurasia

In this paper, we will focus on the woolly rhinoceros, reviewing the human–animal relationship in Europe along a Spain–Poland transect, through Czech Republic, France, Germany, Italy, Moldova, Netherlands, Romania, Spain, and United Kingdom. The aim of the paper is to explore the relationship between rhinoceros and hominins in the form of art evidence, worked bones, raw material use, or food acquisition. We will mostly focus on Neandertals and modern humans behaviour. We will define how this relationship was shaped in Pleistocene and what form it took. It seems that for some reason the relationship was at a distance as indicated by little evidence.

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## CHANGES IN THE CARNASSIAL COMPLEX ALONG THE EVOLUTION OF *LYNX PARDINUS*

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### Keywords

Teeth, *Lynx*, Geometric Morphometrics, Landmarks

In members of the mammalian order Carnivora, the carnassial complex, consisting of the parastyle and paracone of the upper fourth premolar and the paraconid and protoconid of the lower first molar, is of great importance. These are the teeth that the animals use to cut the meat from their preys. These teeth are also very distinctive in each species. In this study we aim to compare the size and shape of the carnassial complex teeth between populations of the species *Lynx pardinus* Temmick 1827, using traditional and geometric morphometric methods. We have focused specially on the geometric analysis. We have used ten landmarks, and a series of semilandmarks to outline the whole carnassial. We have studied both the upper and lower teeth of this complex. Comparing the shape of these teeth between Holocene and Pleistocene Iberian lynxes, we have found that this method clearly discriminates both groups. This separation is also supported by the traditional morphometric analysis. These results allow us to think that there has been at least one change in the Iberian lynxes' carnassial complex along their evolutionary history. We intend to use this method in future studies, including additional species of this genus to the analysis, towards understanding the evolutionary lineage of *Lynx*. Results do not lead to a conclusion on the Pleistocene-Holocene evolution of the Iberian lynx, although they open a new field of study on this subject.





## GASTROCHAENOLITES AS PALEOENVIRONMENTAL INFORMATION TRAPS: THE CASE OF THOLOS DE LA PASTORA (VALENCINA DE LA CONCEPCIÓN, SO SPAIN)

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### Keywords

*Gastrochaenolites*, palaeoenvironment, foraminifera, La Pastora tholos, Chalcolithic

In the slabs of Mio-Pliocene calcareous sandstones used for the covering of the Chalcolithic tholos of La Pastora in the Archaeological Megasite of Valencina de la Concepción-Castilleja de Guzmán (SW Spain), marine bioerosion structures produced in the 3rd millennium BCE were recognized. In this work we focus on the perforations made by the lithophage bivalve *Petricola lithophaga*, called *Gastrochaenolites*, but on its functionality as a trap of the sediment of the environment where they were produced and of which there are no observable outcrops. In particular, the microfaunal content including planktonic and benthic foraminifera as well as ostracod crustaceans was studied. It was able to infer the palaeoenvironmental conditions of the place and time when the slabs used in the tholos were extracted, corresponding to a wide bay. 8 genera of planktonic foraminifera, 20 benthic and 10 ostracod crustaceans have been recognized. Of the former, the most abundant species is *Orbulina universa*, of the benthics *Ammonia beccarii*; and of the ostracods *Loxoconcha elliptica*. The implications of the presence of *Orbulina universa*, *Astrononion stelligerum*, *Elphidium crispum*, *Ammonia beccarii*, *Loxoconcha elliptica* and *Cytherois fischeri* usually tell us of a sector of the bay with a water temperature of no more than 20°C, a bathymetry between the first 25m of depth and with moments of fluvial influence that caused a variation in the salinity of the body of water between 30-35‰, attested by the presence of euryhaline species of ostracods from low energy environments and clay substrates thus confirming estuarine conditions.





## THE ORIGIN OF THE PERFORATED BEADS OF THE MONTELIRIO THOLOS (VALENCINA DE LA CONCEPCIÓN-CASTILLEJA DE GUZMÁN, SW SPAIN)

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### Keywords

beads, Montelirio Tholos, Chalcolithic, geoarchaeology



Valencina de la Concepción-Castilleja de Guzmán Archaeological Zone (SW Spain) is a major resource for the study of the Copper Age (3rd millennium BCE) in SW Europe. Within this mega-site, numerous tholos-type constructions (e.g., Montelirio, La Pastora, Matarrubilla) have been found which contained large number of artefacts and organic remains inside. Into the large chamber of the Montelirio tholos were found over a quarter of a million perforated beads in relation with 7 human bodies inhumed. The chemical analysis of those beads as raw material confirms that the majority of the beads have a calcium carbonate composition and to a lesser extent there are beads of lithic composition (e.g. 10 out of 100 selected beads for this study). It has been noted the presence of two different ornamental structures compatible with marine bivalves: grooves, which correspond to the radial ribs, and concentric lines with growth lines. On the other hand, it has also been recognized bioerosion structures of clionaid sponges that confirms his marine prodence. Taking these characteristics into account and comparing them with shells used during the Chalcolithic and recorded in other archaeological sites, as well as with recent bivalves from areas near the Atlantic coast, the genera with the greatest probability of use are: *Cerastoderma*, *Pecten* and *Acantocardia*, which also reinforce the data on the confined marine environment of Valencina de la Concepción during the Copper Age and the direct relationship of this settlement with the sea.



## PALAEOBIOLOGICAL AND TAPHONOMIC STUDY OF THE FOSSIL REMAINS OF THE BAIO CAVE (GIPUZKOA, BASQUE COUNTRY)

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### Keywords

Pleistocene, *Rangifer tarandus*, Iberian Peninsula, taphonomy

In this work, we present the paleontological remains retrieved on the surface of the Baio Cave (Zestoa, Gipuzkoa) and its paleobiological and taphonomic study. The bone assemblage was recovered mostly by the Antxieta Arkeologi Taldea group in 1990. The faunal assemblage is made up of a wide variety of mammal species, being the most abundant large bovids and cervids. The presence of fauna adapted to cold and/or mountain environments was reported, such as *Rangifer tarandus* (which yielded a direct radiocarbon dating of  $38370 \pm 430$  BP;  $42765 - 42067$  cal BP), *Marmota marmota*, *Rupicapra pyrenaica* and *Capra pyrenaica*. A rhinoceros and different carnivore taxa are also represented: *Ursus arctos*, *Crocuta spelaea*, *Canis lupus*, *Felis silvestris*, being *Vulpes vulpes* the most abundant among the carnivores with 5 individuals represented. The bone surfaces in the assemblage are well preserved, with complete circumferences in most diaphyses. The breakage pattern in long bones is characterized by transverse outlines, oblique angles, and jagged edges. Carnivore activity is present on 24,4% of the fossils, while anthropic activity is minimal (0,9%). The most common taphonomic alterations are related to endokarstic environments, such as manganese oxide staining, carbonate crusts, and cave corrosion holes. Weathering evidence is absent and trampling is rare. Our working hypothesis points towards carnivores as the main accumulation agent, with a scarce human contribution. However, the cave acting as a natural trap for certain taxa (e.g. rhinoceros) cannot be discarded. Additional geochronological data is necessary to understand the temporal framework of the accumulation.





## TAPHONOMY AND ZOOARCHAEOLOGY IN INNER ARCHAEOLOGICAL CONTEXT STUDY OF PALAEOLITHIC DECORATED CAVES

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### Keywords

Taphonomy, Zooarchaeology, Caves, Inner Archaeological Context, Rock Art, Faunal Remains,  
Palaeolithic Age



The Inner Archaeological Context has been defined as remains and traces left by humans and animals inside the caves. The analysis of these remains includes several materials, such as human and animal traces, evidences of activities as lightening and rock art production, anthropic transformation of endokarstic space and any other evidence that offers us historical information about human groups that frequent subterranean landscapes. In this paper we will focus on the faunal remains that have been introduced into the caves through anthropic action. These remains can be traced back to the Middle Palaeolithic, with the case of the Bruniquel cave, although it is from the Upper Palaeolithic onwards that they proliferate until practically the present day. In this work we will mainly present examples from the Upper Palaeolithic and from sites on the Iberian Peninsula such as the caves of Alkerdi II (Navarre) or Altxerri (Gipuzkoa), among others. Faunal remains are relatively common in Palaeolithic decorated caves, either intentionally or accidentally. Animal bones are linked to combustion and lightening remains in some caves, as fuel or even as lamps — this may be the case with some shells. In addition, the anthropic introduction of some taxa has been documented, generally in parietal fissures, related to offerings or symbolic roles. Besides, we can add the activity of troglotauna inside the caves. In this paper, we claim that the taphonomic and zooarchaeological study of these remains is essential to differentiate the accidental animal presence from the related to anthropic activity to understand the activity of humans in caves. According to this, we present some examples in which taphonomy and zooarchaeology show the anthropic activity inside caves with palaeolithic art.



## STUDY OF THE ECOLOGICAL ADAPTATIONS IN THE FIRST DOMESTIC SPECIES BASED ON GEOMETRIC MORPHOMETRICS AND BONE PALAEOPATHOLOGY: THE SHEEP MODEL

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### Keywords

Biomechanics, Domestication, Zooarchaeology, Paleopathology, Geometric Morphometrics

Domestication changed the ecology of animal species, limiting their territorial range and extending to new habitats, which required new adaptations that impacted on skeletal biomechanics. One of the first domestic species documented in the Iberian Peninsula is the sheep, evidencing a rapid adaptation to the new habitats of the west side of the Mediterranean (5500-5000 cal BC). The main objective of this paper was to assess whether the differences in lifestyle and habitat are represented in bone morphology and therefore, to understand how the new ecological adaptation that domestication entailed affected biomechanical characteristics. We present the results obtained with the study of a sample of 10 sheep talus from the Neolithic site of La Draga (5320-4980 cal BC) comparing geometric morphometrics and the pathology osteochondritis dissecans, the latter related in some cases to the physical stress experienced by the animal. For the interpretation of the data, the same methods were applied to modern samples to create a known reference control. The control samples included present-day sheep that lived in contrasting environments: 5 sheeps that lived in open areas, with practically no limits of space, and 6 sheeps that lived in a very small and enclosed space. A wild species, 32 roe deer, has also been used for understand the development of the bone without human implication. Here, we present the results, evaluating the possibilities of their application to the study of bone remains with the aim of inferring the characteristics of the animals' environmental context and exploring the scope of the combined use of these two analytical approaches.





## MORPHOMETRY OF A LATE PLEISTOCENE DHOLE SKELETON FROM LLONIN CAVE (ASTURIAS, SPAIN) AND ITS TAPHONOMIC ORIGIN

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### Keywords

*Cuon*, morphometry, taphonomy, Late Pleistocene

This communication presents dhole (genus *Cuon*) remains found in Late Pleistocene levels (VIII and VI of the Posterior Cone sector) from Llonin Cave (Peñamellera Alta, Asturias). It is a partial skeleton of an adult individual. The traditional morphometric analysis of both cranial and postcranial remains and its comparison with the existing record (published and personal data) allows us to assign this individual to the subspecies *Cuon alpinus europaeus* (Bourguignat, 1868), the typical populations with small teeth well adapted to hypercarnivorism from the European Late Pleistocene. The taphonomic origin and the spatial connection of the archaeological remains at each level were evaluated. In this sense, stratigraphic movement between level VIII and VI were detected, supporting the hypothesis that all dhole remains are from the same individual and that originally would correspond to level VI. The taphonomic study confirms that the dhole remains do not present any type of anthropogenic or carnivore agents' modification, maybe corresponding to a natural death in the cave. However, the appearance of some remains in anthropogenic structures in level VI seems to corroborate an intentional human alterations of primary dhole deposits with a symbolic purpose.





## REASSESSMENT OF THE TAXONOMIC STATUS OF *CANIS ANTIQUUS* (CARNIVORA, CANIDAE) FROM THE EARLY PLEISTOCENE SITE OF MINAARS (GAUTENG, SOUTH AFRICA): IMPLICATIONS FOR THE STUDY OF TROPHIC INTERACTIONS

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### Keywords

South Africa, Plio-Pleistocene, Paleontology, Paleoecology, Canidae



Minaar's cave is a paleontological site dated of ca. 2Ma located in the Cradle of Humankind (Gauteng, South Africa). Few faunal studies were carried out, except for the canids, in particular a complete skull and two mandibles that led to the identification of *Canis antiquus* (syn. *Thos antiquus*). This jackal-like canid completes an already complicated guild (6 genera and at least 12 species). The high specific diversity of this guild in the Plio-Pleistocene questions the taxonomic reality of particular forms: would it be a reflection of past biodiversity or a significant intraspecific variability? In the light of new morphometric studies of the two current species of African jackals (85 *Lupulella mesomelas*; 15 *Lupulella adusta*) as well as the fossil record in southern Africa (278 *Lupulella* spp. from the Cradle), the taxonomic attribution of Minaar's canid has been discussed and the whole set is henceforth reattributed to *L. adusta*. Minaars is a paleontological site surrounded by numerous sites known for their rich paleoanthropological record. Therefore, this study contributes to the characterization of paleoecosystems for this transitional period where both last australopithecines and early *Homo* co-evolved. Indeed, it is the only site having *L. adusta* and *L. mesomelas* in sympatry, questioning the canid's palaeoguild structure with respect to the other sites of the Cradle. By extension, it allows us a reflexion about the ecological status of the whole predator community, including hominins (trophic cascade phenomena).



## A NEW *URSUS DENINGERI* SITE (VON REICHENAU, 1904) IN THE IBERIAN PENINSULA. THE MANDIBLE FROM SALBATORE II CAVE (ITZIAR, DEBA, BASQUE COUNTRY)

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### Keywords

Cave Bears, Geometrics Morphometrics, 3D Scan, Pleistocene

The Deninger's bear (*Ursus deningeri*) is an ancestral form of the cave bear lineage, considered as a chronospecies of *Ursus spelaeus sensu lato*. This species inhabited in Iberia from the late Early Pleistocene, to the Late Middle Pleistocene, including transitional forms. Compared to the late Pleistocene *U. spelaeus*, Iberian *U. deningeri* remains are scarce, only documented in 16 sites. We present a complete mandible recovered from Salbatore II cave. It corresponds to an old individual with eroded teeth and pathological lesions. To assess its taxonomy, we compared with other cave and brown bears. Comparisons were made attending its morphology and using both traditional and 3D geometric morphometrics. These methodologies showed different though complementary results. The mandible is morphologically similar to the cave bear lineage because of a high mandible body and deep masseter fossa. However, it shows a coronoid process leaned backwards, a pointed shape of pterygoid process, and a dorso-ventrally narrow condyle, present in some early and mid-Middle Pleistocene *U. deningeri* and brown bears. Two principal component analyses (PCAs) with traditional measurements showed that Salbatore II fits within the cave bear variation, with a minimum overlap with brown bears once size is accounted for. On the other hand, a geometric morphometric PCA showed that Salbatore II is close to *U. arctos* variation, but within *U. deningeri* variation. According to the general size and the morphological characteristics, Salbatore II shows *U. deningeri* affinities with many ancestral characteristics, which may suggest a minimum mid-Middle Pleistocene chronology, scarce in the Cantabrian region.





## PALAEONTOLOGICAL INVESTIGATIONS IN ÁLAVA-ARABA: STATE OF THE ART

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### Keywords

Northern Iberia, Paleontology, Zooarchaeology, Macromammals, Micromammals

The province of Álava-Araba is located in the north of the Iberian Peninsula (Basque Country, Spain). This territory, located between the southern slope of the Cantabrian coast and the Ebro river valley, has a wide geological, climatic and landscape variety. Unlike neighboring territories, regulated paleontological and zooarchaeological investigations in karstic contexts have been infrequent. The authors of this communication have spent several years collaborating with various authorities and speleological groups in the study of collections and in fieldwork. This has allowed us to carry out a large work of taxonomic identification and spatial distribution of macro and micromammal taxa present in archaeological and paleontological deposits throughout the territory. Among the discovered remains, we can mention three of them, a complete *Castor fiber* skull in Southern Uraska cave (2030±30BP). An almost complete specimen of *Panthera leo spelaea* found in Ledillos cave, Middle-Upper Pleistocene taxa just recorded in northern Iberia. This singular finds are completed by an extensive paleontological ensemble (>5000 NISP) discovered in the Hayal de Guinea cave, related to Upper pleistocene. Among the identified taxa we can highlight the abundance of *Cervus elaphus*, associated to *Rangifer tarandus*, *Ursus spelaeus* and *Marmota marmota*. The development of this project has meant an important change in paleontological and archaeological studies in Álava-Araba. This territory, traditionally linked to Holocene contexts and of anthropic origin. These preliminary results extend to the southern slope of the Cantabrian mountain range the non-analogous biome developed during the last glacial phase.





## IMPLICATIONS OF THE IDENTIFYING OF TOOTH MARKS IN THE BONE ASSEMBLAGE OF VENTA MICENA-3 SITE (GUADIX-BAZA, SPAIN)

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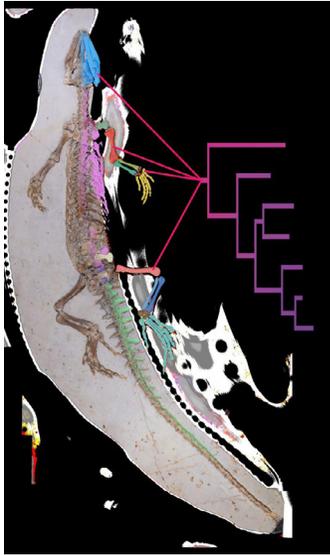
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### Keywords

Tooth marks, Geometric morphometrics, Computational learning, Taphonomy, Early Pleistocene, *Pachycrocuta brevirostris*, Saber-toothed cats

Venta Micena 3 (VM3) (Orce, Gaudix Baza Basin, Spain) is a key site for the knowledge of the Early Pleistocene fauna of the southwestern part of Eurasia. Its relevance stems from the quality of the fossil assemblage, which boasts a great palaeontological diversity. Furthermore, this site has been used as a model to characterise the behaviour of *Pachycrocuta brevirostris*, since this giant hyena has been considered the main agent responsible for the formation of these 1.6-1.5 Myr assemblage. On the other hand, the use of artificial intelligence techniques and 3D geometric morphometry has proven to be a useful tool to characterize tooth marks (pits) of current species. Therefore, the aim of this communication is to characterize the taxonomic origin of the bite marks found in a selection of fossil bones from the VM3 site. Our results indicate that most tooth marks documented in VM3 can be reliably attributed to hyaenids. At the same time, we have also classified tooth marks that are more consistent with the signatures of other carnivores, such as canids and large felids despite the fact that for the latter it had been proposed that they could not leave such signatures on the surface of the bones of the animals on which they fed. In addition, the methodology and results provided by this study can be used as a reference for the taphonomic assessment of other Early-Middle Pleistocene localities.





When it comes to the small world of the Mesozoic, lissamphibians, lepidosaurs, and other small amphibians and reptiles have been studied since the beginning of palaeontology. However, these clades are often misrepresented and overlooked. This led to a biased representation, with described specimens being either fossils preserved in slabs but often deformed and hard to interpret, or isolated fragmented bones, hard to identify. The early evolutionary history and geographical dispersal of several taxa remain, thus, unknown, even though all major modern clades appeared and radiated during the Mesozoic.

New approaches and methodologies are now bringing new insights into amphibians and small reptiles studies. The recent democratization of imaging technology, such as microCT-scanning, allows us to capture details

never seen before in fossils preserved both in slabs and as isolated remains, and reconstruct those which were crushed and deformed. New characters and data can be implemented and used in new phylogenetic models and statistical tools, such as Bayesian Inference, ecological niche modeling, and Geometric Morphometrics, allowing us to understand the Mesozoic diversification of these animals.

This thematic session aims to highlight the most recent studies on the small herpetofauna from the Mesozoic, including lissamphibians, lepidosauromorphs, and other small reptiles. We encourage contribution using recent approaches in palaeontology, but also studying this group in previously poorly reported areas. Indeed, these animals achieved a global distribution matching what is observed nowadays during the Mesozoic, but their fossil records remain scarce in some regions of the globe for certain periods of time. Therefore, description of new material is also invited as this gives new inputs on the evolutionary history and palaeobiogeography of these groups.

# A small new world: modern methodologies and approaches on the study of Mesozoic small herpetofauna

## Organisers

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## Thematic Session



## CARVED INTO BONE: THE FIRST FOSSIL AMPHIBIAN “BRAIN”

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SPOTLIGHT  
TALK

Keywords

Cretaceous, Anura, Paleoneurology, Africa, Tomography



When the Cretaceous pipid frog *Pachycentrata taqueti* was first described from the site of In Becetén (Niger), its extreme ossification of its braincase and vertebrae was remarked as a unique feature among anurans. This ossification was little studied during the formal description of *Pachycentrata*, where it was characterized as pachyosteosclerosis, a unique feature among amphibians. In amniotes, pachyosteosclerosis has been linked to buoyancy controls, as they dive with air filled lungs. As extant pipids can dive with empty lungs, the presence of pachyosteosclerosis could have a different impact on *Pachycentrata*. I here present my results on the tomography of the braincase of *Pachycentrata*, and the analysis of the resulting endocast reconstruction. This analysis revealed an exceptional preservation of brain structures and cranial nerves pathway, with the resulting endocast almost matching the brain of an extant anuran. The main brain structures were identified, from the main olfactive lobes to the cerebellum, including six pairs of cranial nerves (out of the ten known), alongside several vascular pathways. Comparisons to the brain of *Xenopus* and *Pipa* allowed me to infer auditory, visual and olfactive capabilities for *Pachycentrata*. *Pachycentrata* likely had a modified inner ear for an aquatic lifestyle, poorly functioning eyes and a great sense of smell. All these features are similar to the extant *Pipa*, and *Pachycentrata* likely inhabited similar environments, the bottom of dark, muddy and turbid ponds or lakes. Furthermore, the presence of pachyosteosclerosis could indicate that *Pachycentrata* was able to burrow the bottom of lakes to feed, escape predators, or survive a drought.



## FIRST OCCURRENCE OF A SQUAMATE IN THE CENOMANIAN OF ALGORA (GUADALAJARA, SPAIN)

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### Keywords

Iberian Peninsula, Upper Cretaceous, Pythonomorpha, vertebra, pachyosteosclerosis

The Cenomanian (lowermost Upper Cretaceous) is key to understand the vertebrate faunal turnovers that took place between the Early and the Late Cretaceous. This stage is relevant in the diversification of Squamata, since several aquatic groups radically different from those found in the Lower Cretaceous (*i.e.*, 'pachyophiids', 'dolichosaurs' and 'aigialosaurs'), radiated during this period mainly in the Tethys region, and eventually gave rise to mosasaurids. All these lineages were previously recognized in the Upper Cretaceous of the Iberian Peninsula. In this context, the Algora fossil site (Guadalajara Province, Central Spain) is of great interest since it represents the first European Cenomanian site with a high concentration of macrovertebrate remains. The vertebrate faunal assemblage in this site was so far represented by an osteichthyan, a stem and bothremydid turtles, an indeterminate elasmosaurian, two neosuchian crocodiles, a theropod, and a sauropod dinosaur. Recent finds in this locality allowed the recognition of several previously unidentified taxa. In this sense, an isolated and complete squamate vertebra has been recognized for the first time in the Cenomanian of Algora. The aim of this work is to present a detailed anatomical analysis of that vertebra found in the Algora fossil site, discussing its precise systematic attribution. The Algora specimen has been identified as a new species of the pythonomorph genus *Carentonosaurus*: *Carentonosaurus algorensis*. It displays pachyosteosclerosis, indicating an adaptation to shallow-water environments. In this context, the new Spanish taxon represents another pachyosteosclerotic pythonomorph from the European Cenomanian, evidencing the high diversification of the group during this period.





## MACROEVOLUTION OF LEPIDOSAUR BODY PROPORTIONS THROUGH DEEP TIME

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### Keywords

Lepidosaur, Macroevolution, Ecomorphology



Lepidosauria is the largest clade of tetrapods in the world today comprising over 11,500 known species. To analyze the evolutionary rate of lepidosaur phenotypes through time, we constructed the largest existing dataset of their external morphology (head length and width, body length, limb length and tail length) from both fossil and living species. We collected data from ~23,000 specimens from 3,107 species, of which 274 are extinct, and constructed a supertree of all species in our dataset. We log-transformed the data, calculated evolutionary rates of morphological change, and searched for instances along the phylogeny where evolutionary rates either increased or decreased using the RRphylo package in R. The overall evolutionary rate of Lepidosauria was significantly lower than what would be expected under Brownian motion. We identified rate decreases in the Toxicofera, Gekkota, and Lacertibaenia. On the other hand, we found a rate increase in Scincoidea. Rates of Rhynchocephalia did not significantly differ from Brownian motion. When analyzing body mass alone, we found increased rates in Pythonomorpha and decreases in Iguania, Lacertibaenia, and Gekkota. We then analyzed evolutionary rates, as a function of different forms of substrate use (terrestrial, aquatic, fossorial, etc.), and found that fossorial and semi-fossorial species exhibited the highest evolutionary rates whereas generalist and scansorial species had the lowest. We hypothesize that fossorial and semi-fossorial species face the strongest evolutionary pressure, with the largest number of morphological solutions, whereas generalist species do not face strong selection pressure as they possess an ecologically flexible Bauplan.



Ungulata mainly includes large mammals recognizable for the presence of hooves. This clade is characterized by an extraordinary fossil and evolutionary record with a high taxonomic diversity. The members of this clade are often used to both correlate continental fossiliferous deposits and to investigate dispersal patterns and paleoenvironmental changes at local, regional, or global scale. Nevertheless, a comprehensive evolutionary and biochronological framework of the several families, genera and species is long overdue. The taxonomic status of certain groups is strongly debated and different phylogenetic hypotheses have been proposed during the last decades to share new knowledge on their evolutionary history. Herein, we propose a meeting point among researchers in Vertebrate Paleontology to provide a first contribution for an updated taxonomic and phylogenetic framework of Eurasian ungulates, with the aim to develop a new biochronologic and paleobiogeographic frameworks that could lead to well-resolved paleoecological, paleoclimatic and phylogenetic interpretations. We invite researchers to share their research to find a common view on morphological and morphometric characters within the same taxonomic unit, and to constructively discuss any paleobiogeographic and evolutionary hypotheses on the different members of this grand order.

# Late Neogene ungulates from Eurasia: Taxonomy, Biochronology, Paleobiogeography and Evolution

## Organisers

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## Thematic Session



# HÖWENEGG *HIPPOTHERIUM PRIMIGENIUM*: GEOLOGICAL CONTEXT, CRANIAL AND POSTCRANIAL MORPHOLOGY, PALAEOECOLOGICAL AND BIOGEOGRAPHIC IMPORTANCE

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## Keywords

Höwenegg, *Hippotherium*, *Cormohipparion*, Datum, Late Miocene

Höwenegg is an early Vallesian (MN9, 10.3 Ma) vertebrate locality in Hegau, Southwest Germany renowned for its preservation of complete mammalian skeletons, diverse invertebrate and plant fossils. Herein, we present the first photographic images of the Höwenegg *Hippotherium primigenium* skulls, mandibles and dentitions for describing critical character states used to define hipparion species. We compare these states to those for North American *Cormohipparion occidentale*, Turkish *Cormohipparion sinapensis*, Algerian '*Cormohipparion*' *africanum*, Austrian Pannonian C *Hippotherium* sp., Austrian locality Inzersdorf *Hippotherium primigenium*, the China type specimens of *Hippotherium weihoense* and '*Hipparion*' *chiai*, and Moldovan *Cremohipparion moldavicum*. Also provided are univariate statistical comparisons of cranial-dental characters and Log10 ratio analyses of third metapodials dimensions to better evaluate taxonomic comparisons and define the genetic pool from which Old World hipparions are derived. We concur with previous authors that North American *Cormohipparion* is the likely source of first occurring Old World hipparions, offering alternatives of *Cormohipparion occidentale* or *Cormohipparion quinni* as the most closely related species for the Old World *Cormohipparion* Datum. We find that the best evidence for the chronology of the *Cormohipparion* Datum suggests an age of 11.4–11.0 Ma.





## THE PRIMITIVE DEER FROM SANSAN (MIDDLE MIOCENE, FRANCE): EXPLORING TAXONOMICAL CLASSIFICATION OF LOWER DENTITION THROUGH MULTIVARIATE METHODS

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### Keywords

Cervidae, *Dicrocerus*, *Heteroprox*, Teeth, Neogene



The Middle Miocene site of Sansan (MN6), France, possesses an extensive faunal assemblage comprising over 80 species of mammals. Of particular interest are two representatives of the Cervidae, *Heteroprox larteti* and *Dicrocerus elegans*, which share similar size. Recent studies on antler-like remains recovered in Sansan identified two morphotypes of proto-antlers and attributed both to *D. elegans* as a case of sexual dimorphism, similar to what is observed in modern reindeer (*Rangifer tarandus*). However, the potential presence of a third species cannot be excluded. Identifying two species with significant size overlap based mainly on dental characteristics can be challenging. To address the issue, we employed a multivariate approach to preliminarily examine whether it can provide insights into the classification of these species. To investigate the clustering patterns in Sansan deer, a K-means clustering algorithm was applied on a dataset of dental measurements from 486 specimens. Principal component analysis with the resulting clusters revealed significant clustering for 3 groups of individuals. It is important to highlight the presence of two somewhat similar dental morphologies attributed to sexual dimorphism inside the *D. elegans* cluster, with the smaller specimens likely representing females. However, the separation might be mainly size driven, with two major groups attributed to *Heteroprox* and *Dicrocerus*. While these findings support previous research, further analysis is necessary to determine the taxonomic identity of these clusters and their implications for the evolution and diversification of the Sansan fauna. Our study emphasizes the importance of using statistical tools together with morphological analysis and highlights the potential of statistical clustering techniques in exploring morphological variation.



## BIOCHRONOLOGICAL SIGNIFICANCE, TAXONOMIC RICHNESS, AND PALEOECOLOGICAL IMPLICATIONS OF THE FOSSIL RHINOCEROTID RECORD (RHINOCEROTIDAE, MAMMALIA) OF GREECE

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### Keywords

Rhinocerotidae, Greece, Miocene, Pliocene, Pleistocene

The Middle Miocene rhinocerotid record of Greece comprises the teleoceratine *Brachypotherium brachypus* and the aceratheriine *Aceratherium simorreense*, both featuring a continuous biogeographical distribution across Europe. The transition towards the Late Miocene was marked by the Vallesian Crisis. In Central-Western Europe, more temperate and closed habitats persisted, with both genera surviving into the Late Miocene. In the Eastern Mediterranean region, nevertheless, both genera disappeared, probably due to the gradual expansion of more open habitats. In Greece, they were replaced by the aceratheriine taxa *Acerorhinus neleus* and *Chilotherium*, which dispersed from Asia, and the dicerotine *Miodiceros neumayri* of potential African origins. The dicerorhinine *Dihoplus pikermiensis* was the only Late Miocene rhinocerotid of Greece retaining affinities with *Dihoplus schleiermacheri* of Western Europe. The end of the Miocene was marked by a significant faunal turnover caused by the major environmental effects of the Messinian Salinity Crisis, when the Mediterranean Sea entered into a cycle of significant desiccation. The aceratheriines and dicerotines disappeared completely from Europe; only the dicerorhinine genus *Dihoplus* survived into the Pliocene. Following the Zanclean flood, the environmental conditions shifted again towards more temperate and forested habitats. During the Pliocene and Pleistocene, the Greek rhinocerotid record became taxonomically and biostratigraphically on par with that of Western Europe. The scanty Early Pliocene record might be referable to *Dihoplus megarhinus*. Late Pliocene *Stephanorhinus jeanvireti* is documented with ample material. Villafranchian *Stephanorhinus etruscus*, has been reported from several, primarily Early Pleistocene, sites. It was replaced by *Stephanorhinus hemitoechus*, documented in Middle-Late Pleistocene localities. *Coelodonta antiquitatis* is restricted to a single Late Pleistocene locality in Northern Greece, affirming its scarcity at low latitudes.





## NEW EVIDENCE FOR THE UNIQUE COEXISTENCE OF TWO SUBFAMILIES OF CLAWED PERISSODACTYLS (MAMMALIA, CHALICOTHERIIDAE) IN THE UPPER MIOCENE OF ROMANIA AND THE EASTERN MEDITERRANEAN

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### Keywords

Chalicotheres, taxonomy, biogeography, palaeoenvironment, Eurasia

Chalicotheres are a peculiar group of extinct ungulate mammals. They belong to the order Perissodactyla, which includes tapirs, rhinoceroses, and horses, but instead of hooves they had large claws. Chalicotheres are the only ungulate group that evolved this trait. The family Chalicotheriidae consists of two subfamilies, the Schizotheriinae and the Chalicotheriinae. The Upper Miocene locality of Pogana 1 in eastern Romania yielded new chalicothere material. A proximal phalanx of the pes can be assigned to the schizotheriine *Ancylotherium pentelicum*, whereas a partial calcaneum belongs to an indeterminate chalicotheriine. Both specimens were found in the same stratigraphic layer. Thus, the Pogana 1 locality represents one of the very few cases, where the co-occurrence of both chalicothere subfamilies within one fossiliferous horizon in the same fossil site is confirmed. A detailed review of all localities, where the two subfamilies have been reported to co-occur, shows that this is a rare phenomenon, with only eight certain cases. Furthermore, it is almost exclusively observed during the Turolian age in the Balkan-Iranian zoogeographical province, where six of the eight certain cases are found. This may be related to provincial differences in the palaeoenvironment. The data presented here support the hypothesis of a diverse mosaic environment in the Balkan-Iranian province with both closed environments and open habitats that was able to sustain a rich and diverse large mammal fauna, allowing members of both chalicothere subfamilies to coexist without having to compete for food resources.





## PLEISTOCENE MAMMALIAN REMAINS FROM THE SIWALIK HILLS OF SARDHOK, PUNJAB, PAKISTAN

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### Keywords

Artiodactyla, Perissodactyla, Proboscidea, Pleistocene, Siwalik

The Siwalik Group comprises freshwater deposits having age span 18.0-0.6 Ma. The Potwar Plateau of Pakistan covers the most exposed part of the Siwalik, yielding mammalian remains including proboscideans, artiodactyls, perissodactyls and carnivores. Recently collected Pleistocene mammalian specimens from the Siwalik Group of Pakistan are described and discussed in this study. Remains of Early Pleistocene mammals have been reported from the Quaternary basin nearby the Sardhok village in the Gujrat district of the Punjab province, Pakistan. The Early Pleistocene mammals are presented based on the description of the recovered material from the Sardhok outcrops of the Pabbi Hills (Upper Siwalik), and the remains increasingly indicate taxonomic diversity. The described taxa include bovids, cervids, giraffids, hippopotamids, rhinoceroses, equids, and elephants. The bovids are represented by a reasonable number of specimens suggesting that the niche probably was filled by the large bovines. But cervids, rhinocerotids, equids and proboscideans are approximately equally common at Sardhok. Giraffids and hippopotamids present rare findings whereas tragulids and suids are absent. Most of these taxa indicate a predominance of savannah habitat during the deposition of the Pinjor Formation of the Siwaliks. The Pleistocene deposits of the Sardhok also yielded fossil remains of reduncines, caprines, boselaphines, and bovines that are now grazing antelopes found in habitats associated with the open dry regions. The large mammalian fauna, with semiaquatic species (*Hexaprotodon*), indicate the important role of open landscapes throughout the Early Pleistocene of the region.





## NEW INSIGHT INTO THE LATE MIOCENE HIPPOPOTAMID MATERIAL FROM LA PORTERA, VALENCIA (SPAIN)

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### Keywords

Iberian Peninsula, Mammal Neogene Zone 13, Hippopotamidae, *Archaeopotamus*

Several Late Miocene and Early Pliocene hippopotamid species have been described from Peri-Mediterranean fossils sites in Italy, Spain, Libya, Egypt, and Algeria. However, most of these species are documented by scant and/or severely fragmented remains. Among these taxa we find *Hexaprotodon? crusafonti*, which was a small-medium sized hippopotamid, recorded from several Late Miocene localities of the Iberian Peninsula (Las Casiones, Venta del Moro, La Portera, Arenas del Rey, El Arquillo-I), and from an earliest Pliocene French locality (La Mosson). Among the remains ascribed to *Hex.? crusafonti*, there is a left hemi-mandible from La Portera (Valencia), stored in the Museo Nacional de Ciencias Naturales of Madrid (MNCN-CSIC), which we re-describe and analyse here. The hemimandible preserves the third and fourth premolars, the first and third molars, the mandibular symphysis, and three incisors. The mandibular symphysis of the studied specimen is particularly long, the rostral fan is narrow, while the premolar row has a similar length to the molar one. These characters differ from those of the genera *Hexaprotodon* and are listed as diagnostic for the genus *Archaeopotamus*. The studied hippopotamid material is therefore referred to as *Archaeopotamus crusafonti* n. comb. The latter genus is known from various Late Miocene localities of Africa and the Arabian Peninsula and was supposedly recognized from the Late Miocene-Early Pliocene site of Wadi Natrun, Egypt. The presence in Spain of *Archaeopotamus* testifies to a Peri-Mediterranean distribution of the genus during Late Miocene and Early Pliocene and provides new insights on the dispersal pattern of this taxon.





## PLIOCENE RHINOCEROTINA FROM EURASIA: TAXONOMY, PALEOBIOGEOGRAPHY AND BIOCHRONOLOGY

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### Keywords

Rhinocerotidae, morphology, fossil record, dispersal pattern

Although the family Rhinocerotidae was widely distributed in Eurasia during the Neogene, their Pliocene record is still poorly understood as compared with the Miocene one, being documented by few localities and scanty remains. In Palearctic Eurasia, the Pliocene record of Rhinocerotidae is almost restricted to Rhinocerotina, with the presence of at least five genera: *Pliorhinus*, with *P. megarhinus* and *P. miguelcrusafonti*; *Stephanorhinus*, with *S. jeanvireti* and *S. etruscus*; *Coelodonta*, with *C. thibetana*; *Dicerorhinus*, with *D. gwebinensis*; and *Rhinoceros*, with *R. sivalensis*. The Levantine area records the presence of a Late Pliocene species probably related to the Miocene genus *Dihoplus*, '*Dihoplus*' *bethlehemsis*, but the systematic position of this taxon need to be confirmed. The occurrence of *Dihoplus schleiermacheri* during the Early Pliocene is discounted, and these records are instead re-assigned to *P. megarhinus*. The latter species occurs throughout Eurasia, dominating the Early Pliocene Rhinocerotidae record, while its sister taxon, *P. miguelcrusafonti*, is present during the Late Pliocene. *Stephanorhinus* first occurs in Western Eurasia during the latest Pliocene although it widely spreads in the Palearctic region during the Pleistocene. *Coelodonta thibetana*, from the Pliocene of Tibet, shows intermediate morphological features between *Stephanorhinus* and the more derived Pleistocene *Coelodonta*, suggesting a close relationship between the two genera. Finally, a species dubitatively assigned to *Stephanorhinus*, *S.? africanus*, is reported from the Pliocene deposits of North Africa, leading to a new hypothesis on the dispersal pattern of this genus.





## A STUDY OF THE GIRAFFIDAE METAPODIALS VARIATION USING MODERN ANALYTICAL TECHNIQUES

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### Keywords

Geometric Morphometrics, Giraffidae, Metapodials, Shape Analysis

Modern Giraffidae are represented by very few species, however, during the Neogene the family was quite diverse. As such, different forms emerged adapted into different modes of life resulting in various fossil metapodial shapes. During the last years, researchers have focused on the study of the morphology of these metapodials, nevertheless modern methods of shape analysis accompanied by a statistical approach have been neglected. Herein, we present the results of a traditional morphometric analysis as well as of a geometric morphometric analysis (GM) of a total of 169 metapodial specimens of 3 extant and 16 fossil Giraffidae species. Four distinct shape groups were identified, comprising of two extremes and two intermediate shape groups. The two extreme groups include the short and robust metapodials observed in *Sivatherium* Falconer & Cautley 1836 and the long and slender or gracile metapodials observed in the extant *Giraffa* Brisson 1756 species, *Palaeotragus* Gaudri 1861 species, *Bohlinia attica* Gaudry & Lartet 1856, and *Giraffokeryx primaevus* Churcher 1970. Notably, similarities were detected between the modern *Okapia* Lankester 1901 and the fossilized genus *Decennatherium* Crusafont 1952, as they are grouped together in the morphospace. The final group includes all the rest studied taxa that show low shape between them and we believe that can be characterised as intermediate forms.





Behind the Scenes at the Museum  
Drage Harriet B.  
Photography Competition  
(1<sup>st</sup> Prize in Category: Other topics related to  
palaeontology)



**Palaeozoic**

**General Session**





## ASSESSING AND VISUALIZING EUBLASTOID TAXONOMY AND CHARACTER DATA THROUGH MORPHOSPACE OCCUPATION

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### Keywords

Morphology, Geometric Morphometrics, Echinodermata, Paleozoic, Photogrammetry

The utilization of 3D geometric morphometrics allows for the quantification and visualization of variation in shape and proportion through the comparison of homologous features. Eublastoidea, a Paleozoic echinoderm clade with a conservative body plan, is an ideal group for morphometric analysis as their plate junctions are homologous and easily identifiable on all species. Eublastoids have previously been grouped taxonomically by generalized shape types (*i.e.*, globose). These shapes are often used in taxonomic descriptions and have been used as characters in phylogenetic analyses to estimate the evolutionary history of the group. However, the underlying homology of these broad shape types has never been explored therefore, their utility as phylogenetic characters is uncertain. Herein, we apply the first comprehensive use of 3D geometric morphometrics on fossil echinoderms to investigate taxonomic assignments, temporal distribution, and whether the varying proportions of skeletal elements that produce the gross thecal morphology are distinguishable in morphospace. Our results suggest that none of the generalized shape types are distinct in morphospace. The measurement data that was visualized on the plate circling ratios, specifically the deltoid to total height (d:h), show visible patterns and trends in morphospace. Our results suggest that the two eublastoid orders occupy distinct areas in morphospace and familial assignments range from complete overlap to complete isolation in morphospace. Applying modern technological methods to previously explored questions allow for an updated understanding of this important fossil clade and provides a framework for others to assess fossil clades in a similar manner.





## AND THEN THERE WERE NONE: MACROEVOLUTIONARY DYNAMICS OF CONULARIIDA (CNIDARIA, SCYPHOZOA)

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### Keywords

Diversity Dynamics, Survivorship Analysis, Paleozoic, *Conularia*, *Paraconularia*

Although they were formally described at the dawn of the XIXth century, conulariids have been an enigmatic group whose phylogeny has not been clarified until very recently. However, aspects such as macroevolutionary dynamics, ecological representation and paleogeographic distribution have not been widely studied. This research provides the first attempt to examine the diversity dynamics of the group. An updated database was compiled to estimate the generic richness from its appearance in the Upper Ediacaran and extinction in the topmost Triassic. From this database, diversities changes and evolutionary rates were calculated; likewise, a survivorship analysis was applied to two distinct cohorts, based on the two different behaviors identified in their evolutionary dynamics: the first one with genera originated during Ediacaran-Ordovician times and the second one during Silurian-Permian. The analyses show that Conulariida diversity behavior is characteristic of the Paleozoic Evolutionary Fauna, similar to other Paleozoic groups. The decline and subsequent disappearance of the group throughout the Paleozoic and Triassic is due not so much to an increase in the extinction rate, but to a significant decrease in the origination rate, influenced, most likely, by sea level fluctuations. The concave survivorship curves obtained are adjusted to theoretical expectations, but the possible bias in diversity due to the recorded high longevity of *Paraconularia* and *Conularia* cannot be dismissed. Future systematic revision and emended diagnosis of *Paraconularia* species and other Asian genera may fill these gaps within evolutionary history of the group during the Upper Paleozoic.





## THE CARBONIFEROUS GONDWANAN LYCOPHYTE *BUMBUDENDRON*, REVISITED

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### Keywords

Adpressions, Ligule, Lycopsiids, Gondwana, Tire Track Taxonomy



*Bumbudendron* was established to include lepidophyte stems with persistent leaf bases that feature true leaf scars, infrafoliar bladders, and without a ligule pit that were found in the Paganzo Basin of the Carboniferous of Argentina. The holotype also includes a fertile zone instead of the development of strobili characteristic of equatorial lepidophytes. This genus includes five species that span from the Carboniferous to the Permian. Since the description of *Bumbudendron*, the presence of lycophytes with a ligule pit in South America has been reported on several occasions, such as in the Lower Carboniferous of Peru and Bolivia, the Carboniferous of Paganzo, and the Permian of Uruguay. The presence or absence of a ligule or ligule pit is relevant because its occurrence is common in heterosporic lycophytes. Its absence, on the contrary, could lead to a discussion of the affiliation of the fossil taxa to other groups, such as the *Protolopododendrales* or the *Lycopodiales*, or even to the discard of the use of a recognized taxon to name a full tree just by the lack of this character in the holotype, as with the *Lepidodendropsis*-like tree of the Carboniferous of Virginia. *Bumbudendron* was compared with *Tomiodendron* from Angara and Gondwana, a genus characterized by its ligule pit and lack of true leaf scar. After the finding of a ligule-like organ in the type material of *Bumbudendron paganzianum*, we address which lepidophyte characterizes Gondwana and how the ongoing discussion of the tire track taxonomy of lepidophytes affects Gondwanan specimens.



## BIOSTRATIGRAPHIC AND TAXONOMIC STUDIES OF DEVONIAN ACTINOPTERYGIANS, LITHUANIA

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### Keywords

Eifelian, Frasnian, histology, morphotypes, Palaeoniscoidae

Actinopterygii is one of the most successful marine groups, which survived four of the five big mass extinction events on the Earth. Together with chondrichthyans, they represent the dominant fish group among marine and freshwater vertebrates since the Carboniferous, but already were relatively common in the Devonian period. Back then, actinopterygians were widely distributed in aquatic ecosystems of different palaeogeographic provinces. Thus, their remains (isolated teeth, scales, vertebrae, and fin rays) are known worldwide including Europe. However, the Lithuanian Devonian actinopterygians have been studied only sporadically up to now. The present research focuses mainly on the taxonomical identification of ichthyofaunal material using morphological and histological analyses. Additionally, the biostratigraphic framework for the Devonian sequences was analysed based on 300 samples from archived cores of 64 boreholes of Lithuania. As a result, numerous fish remains belong to *Orvikuina* and *Cheirolepis*, respectively. According to the various morphological characteristics, remains of *Orvikuina* can be divided into six while those of *Cheirolepis* into four morphotypes. The histological analysis proved the presence of *O. vardiaensis* in the studied area. The biostratigraphic analysis revealed that *Cheirolepis* occurs in the Middle-Upper Devonian, while *Orvikuina* was only discovered in several Middle Devonian local formations.





## POST-EMBRYONIC DEVELOPMENT OF THE CAMBRIAN EUARTHROPOD *PHALAGNOSTUS* REVEALS GROWTH PATTERNS IN AGNOSTOIDS

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### Keywords

Agnostida, Euarthropoda, Cambrian, Development

Agnostoids are rather minute euarthropods that were for a long time considered highly specialized trilobites. This position was subsequently questioned by discoveries of their appendages that differ considerably from those in trilobites, and therefore some authors regarded agnostoids as stem-mandibulates. Despite the locally common occurrence of agnostoids in Cambrian and Ordovician strata worldwide, their post-embryonic development is poorly known. Herein, we describe the ontogenetic sequence of the Cambrian agnostoid *Phalagnostus nudus* (Beyrich, 1845) from Miaolingian strata of Bohemia. Detailed measurement of more than 70 specimens reveals that the development of *Phalagnostus* consists of eight or, at most, nine instars. Similar to trilobites, the early development of *Phalagnostus* is characterized by successive release of thoracic segments from the pygidium, but, unlike them, the subterminal addition of new segments is not morphologically distinguishable. The morphological similarities between juvenile and adult pygidia might suggest, that agnostoids grew by epimorphosis. Ontogeny of *Phalagnostus* further suggests that the meraspid (= juvenile) development was in some agnostoids much shorter (= consisting of only three instars) than previously inferred. The five or six holaspid (= morphologically mature) instars correspond to the number of holaspid instars in the Middle–Late Ordovician agnostoid *Trinodus elspethi* (Raymond, 1925) and suggest that some agnostoids might have had a determined development with a definite number of instars.





## PALEOBIOLOGY AND PALEOECOLOGY OF THE MYRIAPODS FROM THE MONTCEAU-LES-MINES LAGERSTÄTTE (305 MA)

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### Keywords

Carboniferous, Myriapod, Pentazonia, Juliformia, Microtomography

The Montceau-les-Mines Lagerstätte is a fossil site with an exceptional preservation located in the north-east of the Massif Central, France. Dated from the Upper Carboniferous (Kasimovian, 307-303.7 Ma), it was near the equator and yield a diverse and abundant tropical flora and fauna that inhabited humid and swampy paleoenvironments. The defining characteristic of Montceau-les-Mines is the three-dimensional preservation of its flora and fauna inside sideritic nodules. The fauna, dominated by arthropods (e.g., crustaceans, arachnids), but also includes many molluscs, annelids and some vertebrates (e.g., fishes, tetrapods). Our study is focused on one important arthropod group from the locality, the myriapods, for which two species have been described in Montceau: *Amynilyspes fatimae* and *Blanziulus parriati*. We re-studied these two species using X-ray microtomography (micro-CT) and rendered the body and appendage morphology in three dimensions as well as some internal organs (ex : digestive tract) and previously undescribed anatomical structures before (ex: mandibles, sexual appendages). These new morphological data allowed us to discuss the paleoecology of these Carboniferous myriapods such as their diet and defensive behaviour. The new structures we obtained helped us to code these two taxa inside a Diplopoda phylogeny confirming that *Amynilyspes fatimae* is a Pentazonia millipede (as a sister group of Sphaerotheriida) while *Blanziulus parriati* is inside the Juliformia superorder.





# THE DIVERSITY OF CAMBRIAN BIVALVED ARTHROPODS AND THE ORIGIN OF MANDIBULATES

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## Keywords

Arthropods, Cambrian, taxonomy, Burgess Shale

Mandibulate arthropods illustrate a story of evolutionary success, representing one of the most diverse and morphologically disparate animal groups today. This diversity currently includes the myriapods and the pancrustaceans, two groups whose origins have not yet been fully explored through the fossil record. There is increasing evidence, though, that a group of carapace-bearing Cambrian arthropods, commonly known as “bivalved arthropods”, are some of their earlier lineages, opening a new window of exploration for the origin of this group. Reconstructing the affinities of many of these taxa, however, is still hindered by a lack of anatomical information on their head appendages and limbs. Furthermore, despite increasing fossil discoveries, a comprehensive review of their anatomy and classification is still pending. Here, we review the general anatomy of this group and show new findings provided by the genus *Odaraia* from the Canadian Burgess Shale Formation (Wuliuan, Cambrian). This material shows a pair of rounded mandibles with a row of differentiated teeth, analogous to those of extant mandibulates, reinforcing the affinities between both groups. Furthermore, we illustrate the diversity of Cambrian bivalved arthropods across Cambrian Konservat-Lagerstätten, reviewing potential subgroups and highlighting areas that need further exploration. Strikingly, Cambrian arthropods show a wide disparity in carapace shapes and cephalic conformations that cannot be explained by preservation biases alone. This disparity, instead, most probably showcases an early exploration of the morphospace by stem mandibulates, as well as an increasing specialization of the head into a feeding unit towards the crown group.





## MIDDLE-LATE PERMIAN TRACE FOSSILS FROM THE ARGANA BASIN (WESTERN HIGH ATLAS, MOROCCO): ICHNOLOGICAL CONTEXT AND PALAEOECOLOGICAL SIGNIFICANCE

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### Keywords

Invertebrates, Vertebrates, Ichnology, Palaeoenvironment, Argana, Morocco

Morocco has an outstanding vertebrate and invertebrate ichnological record from uppermost Permian deposits. The middle late Permian continental succession of the Argana Basin yields a diverse and abundant ichnological record. It is an extensive sedimentary sequence consisting of fine-grained to conglomerate red beds of fluvial origin. During recent field work several new sites with trace fossils have been discovered from different localities of T2 (Tourbihine member). Here we present a moderately diverse assemblage of invertebrate and vertebrate traces. Among the ichnotaxa discovered are: *Archaeonassa fossulata*, *Arenicolites*, *Diplichnites*, *Helminthoidichnites tenuis*, *Planolites*, *Skolithos verticalis*, *Scoyenia gracilis*, *Sphaerapus larvalis*, *Spongiomorpha carlsbergi*, *Batrachichnus*, *Dromopus*, *Erpetopus*, *Hyloidichnus*, and indeterminate tracks. This recently discovered vertebrate and invertebrate ichnofauna helps to better reconstruct the palaeoenvironment and the palaeoecological complexity of the Permian Argana basin.





## CLASSIFICATION AND PALEOECOLOGY OF CRINOIDEA FROM BUKIT BUCHU (EARLY CARBONIFEROUS), TERENGGANU

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### Keywords

Crinoid, Classification of Crinoidea, Paleocology

This study presents a comprehensive classification and paleoecological description of Crinoidea fossils from Bukit Buchu, Terengganu, Malaysia, in the Early Carboniferous period. Bukit Buchu outcrop is situated on the east coast of Peninsular Malaysia and is part of the Carboniferous system. The Carboniferous Period occurred during the late Paleozoic Era. Since there is currently no comprehensive publication detailing the record of crinoid species that can be found at the area, therefore, study on crinoids will help to confirm the age of Bukit Buchu beds. There are six crinoids successfully discovered onsite. The crinoids found were determined by their calyx morphology with the aid of a stereo zoom advanced research microscope (Nikon AZ100M). Crinoids from subclass Camerata and Cladida have been identified from Bukit Buchu. These are the two distinct groups that occurred only during the Paleozoic. This research contributes to the baseline record of Crinoidea from the East Malaya Block, enhancing knowledge of the fauna and their paleoecology during the Early Carboniferous in the area.





## THE TRUTH COMES OUT OF THE YOUTH'S MOUTH: NEW INFORMATION ON THE POROLEPIFORM *QUEBECIUS QUEBECENSIS* FROM JUVENILE SPECIMENS

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### Keywords

*Quebecius quebecensis*, porolepiform, skull, camera lucida

Porolepiforms are a poorly diversified group of sarcopterygian fishes that primarily lived during the Devonian (419.2-358.9 Ma). With rare exceptions, most taxa are known solely from few specimens. The Late Devonian (middle Frasnian, 375 Ma) holoptychiid porolepiform *Quebecius quebecensis* from the Escuminac Formation of Miguasha, Québec, Canada is known from approximately 50 specimens. However, only few detailed descriptions and illustrations have been made of the skull of juvenile specimens. Here, illustrations of new complete juvenile skulls were made with a camera lucida, bringing new data for the description of the skull. Total length of the new juvenile specimens varies between 48 and 102 mm. The complete and well-preserved skulls enable us to describe cranial bones that are usually fused in adults. For the first time, we can examine, among other things, the unfused condition of the quadratojugal, squamosal and subsquamosal, as well as a complete maxilla, which has never been described before. These latest discoveries are taken into account in the new reconstruction of the skull of *Q. quebecensis*.





## TAXONOMIC REASSESSMENT OF A MOUNTED DICYNODONT SKELETON AT THE FIELD MUSEUM OF NATURAL HISTORY

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### Keywords

Dicynodontia, *Aulacephalodon peavoti*, Karoo Basin, Synapsida, Permian



FMNH UC 1532 is a large dicynodont skeleton from the Karoo Basin (?*Cistecephalus* Assemblage Zone, late Permian) of South Africa, currently on display at the Field Museum of Natural History in Chicago, Illinois. This specimen has been historically referred to *Dicynodon tigriceps*, *Aulacephalodon peavoti*, and *Rhachiocephalus* sp.; it is currently labeled as *A. peavoti*. The holotype specimen of *Aulacephalodon peavoti* (MMK 4237) is partially lost, and illustrations of the missing skull show no significant differences from the type species *A. bainii*, making the taxonomic validity of this species dubious. However, FMNH UC 1532 displays numerous differences from *A. bainii* in cranial and postcranial morphology. A reassessment of FMNH UC 1532 reveals numerous cranial differences (e.g., lack of tusks, zygomatic bosses, or a transverse naso-frontal ridge) that suggest this specimen cannot be referred to the genus *Aulacephalodon*, and is unlikely to even be a member of Geikiidae. Phylogenetic analysis instead recovers FMNH UC 1532 as a basal rhachiocephalid, sharing a combination of cranial characters with *Kitchinganomodon* and *Rhachiocephalus* (e.g., inflated pineal boss, ventrally expanded nares, and a reduced lateral caniniform buttress). The cranium and postcrania of this specimen lack some synapomorphies shared by *Kitchinganomodon* and *Rhachiocephalus* (e.g., an anteriorly positioned and anterodorsally-oriented pineal foramen, lack of the labial fossa), suggesting that FMNH UC 1532 may represent a distinct species of large dicynodont. The mosaic of rhachiocephalid- and geikiid-like characters present in this specimen highlights the complexity of character evolution in “cryptodont” dicynodonts, which complicates the monophyly of this group.



## KUNGURIAN ENVIRONMENTS AND PLANT COMMUNITIES IN THE ATHESIAN VOLCANIC GROUP (SOUTHERN ALPS, N-ITALY)

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### Keywords

Kungurian, Megacaldera, Lithofacies, Palynology, Palaeoenvironmental Reconstructions

Kungurian (late Cisuralian) tropical terrestrial ecosystems and climate have been scarcely investigated with integrated approaches. We applied lithofacies, palynological and stable carbon isotope analyses to two Kungurian successions belonging to the same sedimentary formation within the Athesian Volcanic Group (~289-274 Ma). They were deposited during a phase of volcanic quiescence in a megacaldera and are intercalated between radiometrically dated volcanic units. In this phase the megacaldera was probably divided into several more or less communicating basins with paleotopographically influenced shallow water bodies. Sedimentological analyses combined with palynofacies studies allowed the reconstruction of the different depositional environments developed in the megacaldera. The qualitative and quantitative study of the sporomorphs, in combination with their botanical affinities (parent plants or plant groups) and the inferred plant ecoclimatic preferences (xeromorphic, xeromorphic-hygromorphic, hygromorphic) allowed us to reconstruct the plant communities, their distribution and the changes related to local climate conditions throughout the studied interval. The stable carbon isotope values are comparable with those of other Cisuralian continental plant material. The  $\delta^{13}\text{C}_{\text{org}}$  records evidence for a small variability, which correlates significantly with the abundance of xeromorphic elements. All observations support deposition during semiarid to arid climate conditions, typical of the mid-late Cisuralian in the area, without major climatic shifts. The same multidisciplinary approach will be applied to other sedimentary formations distributed within the megacaldera to obtain new insights into the development of the ecosystems during the activity of the Athesian Volcanic Group.





## EARLY SARCOPTERYGIAN MORPHOLOGICAL DISPARITY

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### Keywords

Geometric Morphometrics, Morphospaces, Osteichthyans, Paleozoic



Sarcopterygian (lobe-finned) and armoured jawed “placoderm” fishes dominated Devonian waters (419 – 359 million years ago). At that time, a new sarcopterygian lineage emerged — the tetrapods — that subsequently colonized the land after the Late Devonian biodiversity crises. Major anatomical adaptations related to this ecological transition marked the early evolutionary history of sarcopterygians. Here we present geometric morphometrics analyses of the body and skull morphological disparity of early sarcopterygians. Three analyses were performed by digitizing 2D landmarks and semi-landmarks on revised reconstructions of the whole body, the lateral view of the skull, and the skull roof. Morphospaces were based on the first two axes of principal component analyses. We found that a major shift of body shape occurs between the Devonian and the Carboniferous. It can be mainly explained by the rise of coelacanths in the early Carboniferous which have shortened bodies with triphycercal (tri-lobed) caudal fins, whereas the shape of Devonian lungfishes and allies is more fusiform with heterocercal caudal fin. The main disparity found within the skull roof concerns the parietal and postparietal bones that are more elongated and anteriorly positioned in coelacanths, “osteolepiforms” and “porolepiforms”, and shortened and posteriorly positioned in tetrapods and lungfishes. Furthermore, a dorsal migration of the eyes occurs in elpistostegalians and tetrapods. Finally, the disparity of the cheek region is mainly explained by the decrease of skull depth in “osteolepiforms”, and the size and position of the opercular series. The shifts of body and skull morphology in early sarcopterygians, especially in the most derived “osteolepiforms”, could be related to the rise of tetrapods and the water-land transition.



## CHARACTERIZATION AND EVALUATION OF EPIZOANS ON THE MIDDLE DEVONIAN PARASPIRIFER

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### Keywords

Morphology, Paleoecology, Epibionts, Brachiopoda, Morphometrics



The preservation of symbiotic relationships in the fossil record provides a wealth of information regarding microcommunity paleoecology. The Middle Devonian Silica Shale Formation represents a shallow, tropical, marine environment that preserves a window into ancient symbiotic relationships. A large population of spiriferid brachiopods (*Paraspirifer bownockeri*) hosted symbionts from a diverse array of organisms. This study combines qualitative work and quantitative 3D geometric morphometrics to evaluate epibiont-host relationships and infer life position of the host brachiopods. Over 200 specimens of *Paraspirifer bownockeri* with epibionts were chosen for examination from the University of Michigan Museum of Paleontology collection. Dimensional measurements were taken of each specimen, epibiont presence/absence and placement was recorded, and 3D models were produced of a subset of 50 specimens. Nine fixed landmarks and 791 surface semilandmarks were placed in 3D Slicer to capture shell surface variations. Principal Component Analysis and cluster analysis were performed on the collected epibiont occurrence data to examine epibiont preferential tiering and preferential co-occurrence with other epibionts. We evaluated the possible life positions of the host brachiopods and examined the co-occurrence of certain epibionts on each valve and patterns of epibionts layering. Results indicate that certain epibionts preferentially encrust particular locations on the host, likely due to location preferences for feeding in the water column. Qualitative examination and characterization of epibionts in concert with 3D geometric morphometrics provides a comprehensive approach to exploring morphological patterns and paleoecological interactions.



## EVOLUTION OF BRACHIOPOD SYMBIOSIS IN THE EARLY PALEOZOIC

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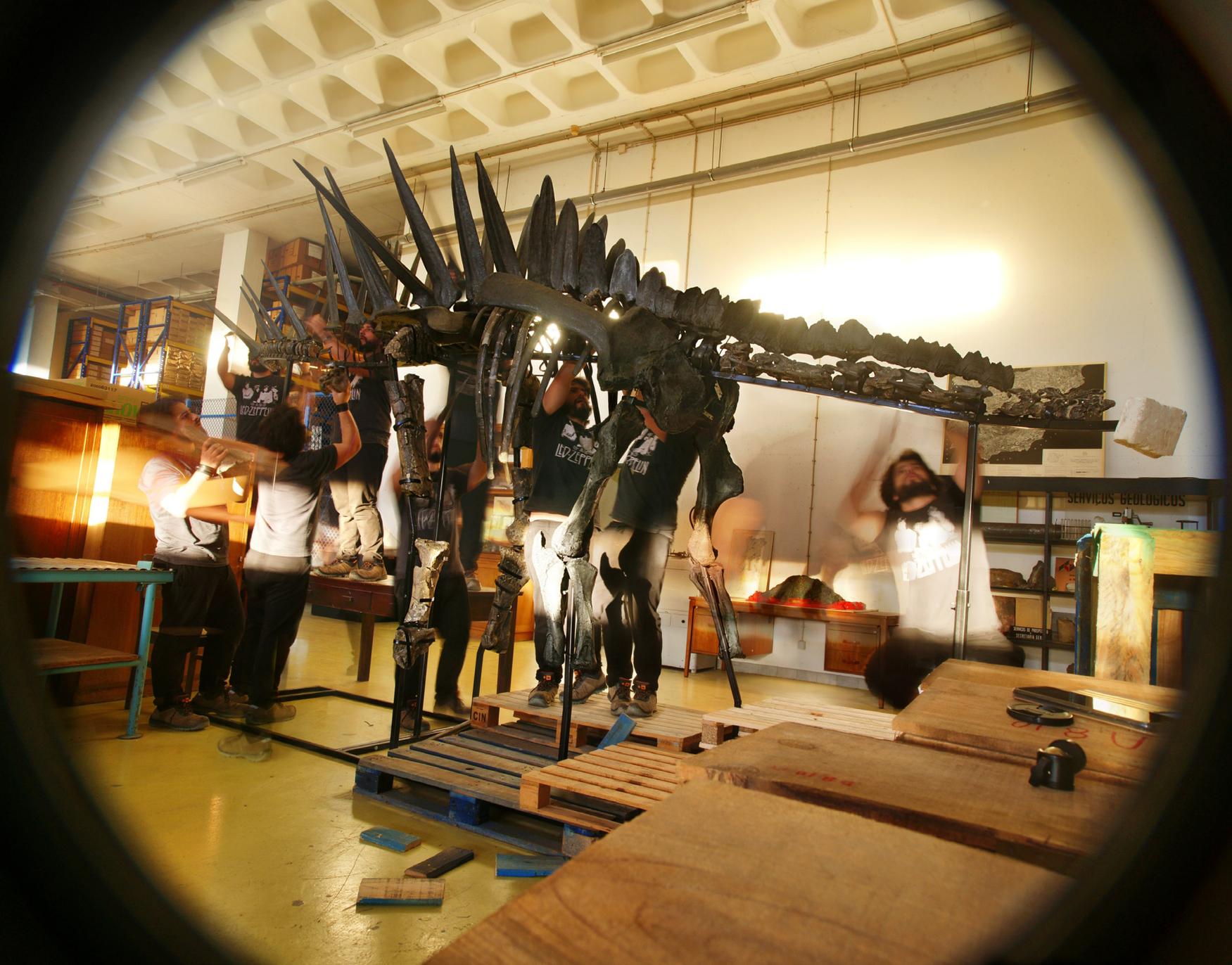
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### Keywords

Brachiopods, Cambrian, Ordovician, Silurian, Symbiosis

Brachiopods were both hosts to the other invertebrates (*i.e.*, epibionts and endobionts) and symbionts in/on various other organisms. The Cambrian brachiopods had symbiosis with various invertebrates such as sponges, molluscs, eldoniids, other brachiopods, cnidarians, cancelloriids, entoprocts and algae. Cambrian brachiopods slightly preferred sponges as partners over the other organisms. Ordovician brachiopods also formed symbiotic associations with various invertebrates such as boring annelids, bryozoans, other brachiopods, corals, echinoderms, molluscs, sponges and tentaculitoids. The Ordovician symbiotic associations were dominated by lophophorates. Bryozoans and boring annelids were the most important partners with Ordovician brachiopods. Similarly, the Silurian brachiopods had symbiosis with various invertebrates such as other brachiopods, bryozoans, corals, echinoderms, stromatoporoid sponges and tentaculitoids. The Silurian symbiotic associations were dominated by lophophorates. Encrusting tentaculitoids and bryozoans were the most important partners to the Silurian brachiopods. There are 29 symbiotic associations involving brachiopods known from the Cambrian, 65 from the Ordovician and 30 from the Silurian. Symbiotic associations involving brachiopods remained relatively uncommon until their explosion in the Late Ordovician. Cambrian, Ordovician and Silurian brachiopods had similar proportions of symbiotic and non-symbiotic taxa. Ordovician lingulids were not significantly more symbiotic than those in the Cambrian, but the Silurian lingulids were significantly more symbiotic than the Ordovician ones. The lingulids were not significantly more symbiotic or less symbiotic than rhynchonelliforms in the Cambrian and Ordovician. In contrast, lingulids were significantly more symbiotic than rhynchonelliforms in the Silurian.





A peak through some of a paleontologist's tasks  
Da Costa Pinto Francisco Joao  
Photography Competition  
(1<sup>st</sup> Prize in Category: Taphonomy and Ichnology)



**Mesozoic**



**General Session**



## FRAGMENTARY REMAINS OF A METRIORHYNCHID CROCODYLOMORPH FROM THE MIDDLE OXFORDIAN OF FRANCE — THE OLDEST KNOWN RHACHEOSAURIN?

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### Keywords

Upper Jurassic, Thalattosuchia, Metriorhynchinae, Lorraine, Terrains à Chailles Formation

Metriorhynchidae is an extinct clade of pelagic crocodylomorphs known from the Middle Jurassic to Lower Cretaceous. Differing from other crocodylomorphs, they evolved paddle-like limbs, a tail fluke, and numerous other adaptations to a likely purely marine lifestyle. The currently best documented metriorhynchid subclade is Rhacheosaurini, which is represented by 13 named species reported from Kimmeridgian to Valanginian sites across the Americas and Europe. Several of these species are known from articulated material, sometimes even bearing soft tissue preservation. Despite considerable research, the origins of this subclade within the subfamily Metriorhynchinae are only barely resolved. Current phylogenetic analyses suggest an emergence of rhacheosaurins during the Oxfordian; however, knowledge on Oxfordian metriorhynchid diversity is comparatively poor, complicating a further assessment of this question. Here, we describe a metriorhynchid rostrum fragment from the collection of P. L. Maubeuge, now housed in the Paleontological Collections in Tübingen, Germany. The rostrum lacks its anterior tip and intact teeth, although the imprint of one tooth crown is preserved. The specimen has been recovered from middle Oxfordian strata near Frémeréville-sous-les-Côtes in Lorraine, France. Phylogenetic analyses using maximum parsimony nest the specimen among other barely understood material, including "*Metriorhynchus palpebrosus*" and "*Cricosaurus saltillensis*", together forming a distinct clade within Rhacheosaurini. If confirmed, the specimen would not only improve our knowledge on Oxfordian metriorhynchid diversity but would also represent the currently oldest known rhacheosaurin and suggest an origin of Rhacheosaurini prior to the middle Oxfordian.





## THE LONG ROAD TO RECOVERY: BENTHIC ECOLOGICAL RECOVERY FROM THE EARLY TOARCIAN (JURASSIC) MASS EXTINCTION EVENT IN THE CLEVELAND BASIN, UK

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### Keywords

Toarcian Oceanic Anoxic Event, Lower Jurassic, marine ecosystems, diversity, palaeoecology



The Cleveland Basin of Yorkshire, UK, hosts one of the most iconic Lower Jurassic rock successions for studying the Toarcian Oceanic Anoxic Event and the associated mass extinction, yet our understanding of the subsequent recovery is limited. This study documents for the first time the full extent and nature of benthic macrofaunal recovery from the early Toarcian mass extinction event within the Cleveland Basin. Following the extinction event low benthic oxygen levels allowed specialist, low diversity communities to dominate during deposition of the Mulgrave Shale Member (Serpentinum Zone). True recovery only commenced once sea floor ventilation began to improve, this was first expressed by expansion of ecological tiering levels. Recovery advanced slowly thereafter with the possible return to oxygen restricted environments hindering progress during the Variabilis – early Thouarsense ammonite zones. During the subsequent Dispersum – Aalensis zones sand-dominated deposition reoccurred within the basin, this was coincident with an acceleration in recovery when both ecological and species richness exceeded pre-extinction levels. Full recovery within the basin did not occur until the latest Toarcian, approximately seven million years after the extinction. This duration for recovery is on par with estimates of recovery rates from the largest mass extinction of the Phanerozoic – the end-Permian mass extinction event.



## POPEYE'S POLYCHELIDAN LOBSTER IS AN ANCIENT, JURASSIC RELATIVE, OF EXTANT POLYCHELIDS

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### Keywords

Polychelida, Italy, Crustacea, Decapoda, Osteno

In Triassic and Jurassic, there were almost no crabs. Instead, lobster-like crustaceans were represented by some lobster-like crustaceans with a peculiar morphology involving four to five pairs of claws (only the first being large). These lobsters, the polychelidans, are still extant, but now restricted to a single family, the Polychelidae Wood-Mason, 1874 restricted to deep waters. In the Sinemurian Konservat-Lagerstätte of Osteno (Italy), one of these lobsters, *Coleia popeyei* Teruzzi, 1990, is characterized by its relatively small size (total length: 15-40 mm) and large, thick claws from which the specific epithet derives. This species was assigned to *Coleia* Broderip, 1835, a genus to which up to 43% of all fossil species were placed, and which has been suggested to be polyphyletic. Our review of the type material shows it is not a *Coleia* or Coleiidae Van Straelen, 1925, but a Polychelidae, a member of the only surviving family. We therefore assigned this species to the new genus *Teruzzicheles* Audo & Charbonnier, 2022. This is not the earliest representative of this group, but it fills a 34 million-year gap in its fossil record. Besides, the small size and claw shape of this species are probably due to a neotenic evolution also documented in a few other fossil and extant polychelidans.





## HERITAGE OF JURASSIC PROGONOCIMICIDAE FROM EUROPE (HEMIPTERA: COLEORRHYNCHA)

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### Keywords

Palaeoecology, Palaeoentomology, Palaeodiversity, Moss Bugs, Classification, Fossil Record

Coleorrhyncha, also known as moss bugs, are nowadays represented by a single family Peloridiidae confined to Patagonia, New Zealand, Australia and New Caledonia. The remaining families of the suborder have gone extinct, *i.e.*, the Hoploridiidae (Aptian; Transbaikalia), Karabasiidae (Toaracian–Aptian; Kazakhstan, Kyrgyzstan, Russia, Mongolia, China), and Progonocimicidae. The most diverse Progonocimicidae comprise 26 genera, from Australia, Asia and Europe, from Permian (Changhsingian) to the Cretaceous (Cenomanian). It is traditionally subdivided into two subfamilies, including Progonocimicinae and Cicadocorinae, but some taxa included within them are in need of revision. The condition of the known fossils varies from vestigial (represented by isolated wings) to completely preserved specimens. So far, only two taxa are reported from fossil resins. For this reason, many diagnoses are based on wing features exclusively and numerous former descriptions of taxa were given briefly, being insufficiently illustrated. Systematic placement of the recently described Permoridiidae from Germany is very controversial, and it is probably outside of the Hemiptera. European fossil record of Progonocimicidae is scarce, covering *Archicercopis* from the terminal Triassic, *Ecercopis*, *Indutionomarus*, and *Procercopis* (Progonocimicinae) from the Jurassic, and *Ildavia*, *Valdiscytina*, and *Yuripopovia* (Cicadocorinae) from the Lower Cretaceous. I report new specimens from the Jurassic of Germany and Luxembourg, which represent new genera and species belonging to Progonocimicidae. My discovery illuminates taxonomic diversity of progonocimicids, revealing new and unique features, and deepening our understanding of morphological disparity of moss bugs in the Mesozoic. The new data enable me to present a new interpretation of palaeoecology and taphonomy of these insects.





## CENOMANIAN ISOPODS FROM FRANCE AND LEBANON

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### Keywords

Crustacea, Isopoda, Cirolanidae, Valvifera, dermoliths



Isopods (Crustacea, Isopoda) are a very cosmopolitan order. Today they live everywhere from ocean abysses to deserts. Crustaceans are rarely preserved in the fossil record, which is especially true for isopods. Thus, their evolutionary history is still poorly known. To achieve a better understanding of their evolutionary process, we have studied six specimens from the paleontological collections of the Muséum national d'Histoire naturelle, Paris. Two are from the middle Cenomanian of the Sables et Grès du Mans Formation (Sarthe, France) and four from the late Cenomanian of Hadjula (Lebanon). Late Cretaceous crustaceans suggest a great period of faunistic turnover, making their study a priority. The specimens from the lithographic limestones of Lebanon are described as belonging to a new species of isopod *Cirolana* sp. nov. (Cirolanidae), as well as a probable species of valviferan isopod (Valvifera), left in open nomenclature. The specimens from the Sables et Grès du Mans Formation (France), despite being poorly preserved, most likely belong to different cirolanid species from the ones described from the same formation. The presence of dermoliths, a pre-moult accumulation structure specific to terrestrial isopods, has been observed in one of the cirolanid specimens from France and two from Lebanon. This could be key to understanding the terrestrialization of isopods. Finally, we observed a lot of resemblance between *Cirolana* sp. nov., *C. cottreaui* (Lebanon, Santonian) and *C. garassinoi* (Lebanon, Santonian), showing once again strong affinities between the Santonian and Cenomanian faunas from Lebanon.



## NEW DATA ON THE FAUNAL ASSEMBLAGE OF THE MESAVERDE FORMATION (LATE CRETACEOUS, CAMPANIAN) OF THE BIGHORN BASIN, WYOMING, U.S.A.

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### Keywords

Biogeography, Cretaceous, Laramidia, Mesaverde Formation

Campanian-aged assemblages provide large samples of Cretaceous terrestrial environments in Laramidia. Yet, significant gaps remain, particularly for zones between northern outcrops (Alberta, Saskatchewan, and Montana) and southern ones (Utah, New Mexico, Texas, and Coahuila). The Mesaverde Formation of Wyoming remains comparatively understudied. Beginning in 2019, the Raymond M. Alf Museum of Paleontology identified new fossil vertebrate localities in the western Bighorn Basin and re-collected historic sites in the eastern Bighorn Basin, creating a transect spanning terrestrial (west) to marine (east) paleoenvironments. Chondrichthyans are abundant in the eastern localities, with a mix of marine, brackish, and freshwater forms as noted by earlier researchers. The hybodont *Meristodonoides* is shared with other formations of the same age. Amphibians, especially *Scapherpeton*, are surprisingly abundant in the eastern, marine-influenced, sites. *Adocus* is the most common testudine in eastern localities, followed by trionychids; trionychids are most common in western sites. Mammal teeth in the eastern sites include a large m3 (3.7 mm long by 2.1 mm wide) possibly referable to *Turgidodon praesagus*, a new record for the Mesaverde Formation. Hadrosaurids are the most common non-avian dinosaur, represented by teeth of sizes consistent with juvenile individuals. Tyrannosaurid teeth occur alongside small theropod teeth referable to *Richardoestesia gilmorei* and two morphotypes of Dromaeosauridae. Hesperornithiform birds of variable sizes in the eastern sites can be diagnosed to *Hesperornis*, and others can only be assigned to higher taxonomic levels. Further study of the Mesaverde Formation in the Bighorn Basin will allow more detailed comparisons with penecontemporaneous assemblages.





## APPENDICULAR ANATOMY OF THE UPPER CRETACEOUS IBERIAN TURTLE *ALGORACHELUS PEREGRINA* (PLEURODIRA, BOTHREMYDIDAE)

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### Keywords

Testudines, Cenomanian, Spain, Humerus, Femur



The finds of turtle fossils in vertebrate paleontological sites are relatively usual. However, they are generally represented by disarticulated plates or partial to, less usually, complete shells. The availability of appendicular bones of this group of reptiles is much more limited. But, in addition, the studies on these last remains are very scarce in relation to those on the shell or on the cranial skeleton. One of the oldest representatives of the crown Pleurodira in Laurasia is the bothremydid *Algorachelus peregrina*, being the only identified in the pre-Santonian levels in this continent. Hundreds of remains of this aquatic turtle have been found in its type locality: the Cenomanian fossil site of Algora, in Guadalajara (Central Spain). The preserved assemblage includes a greater number of appendicular elements than those identified for any other European Mesozoic pan-pleurodiran turtle, including, among others about ten humerus and ten femurs. All of them are identified as isolated elements. Thus, this site gives the opportunity of study in detail the morphology of the humerus and femur of this bothremydid turtle, appendicular information on very few representatives of this abundant and diverse lineage being so far available. Three-dimensional virtual models of these bones have been obtained to facilitate their comparative and morpho-functional study. The description of the appendicular elements of this Spanish turtle relative to those of other extant and extinct pleurodires provides us new data on the palaeobiology of the taxon.



## AN ARTICULATED BAENID TURTLE FROM THE LANCE FORMATION (LATE MAASTRICHTIAN, LATE CRETACEOUS) OF THE ROCK SPRINGS UPLIFT, SWEETWATER COUNTY, WYOMING, U.S.A.

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### Keywords

Baenidae, Testudines, Lance Formation, Cretaceous

Although the vertebrate faunal assemblage is relatively well documented for many exposures of the Lance Formation in Wyoming, outcrops of the Rock Springs Uplift in southwestern Wyoming are comparatively unexplored. In 2019, high school students from The Webb Schools and the Raymond M. Alf Museum of Paleontology (RAM, Claremont, California) discovered an articulated baenid turtle skeleton in a channel sandstone in the upper third of the Lance Formation in Sweetwater County, Wyoming. Although the skull and much of the carapace were destroyed by erosion prior to discovery, the remainder of the skeleton remains. The specimen, RAM 24819, is tentatively referred to *Eubaena hatcheri*, based on its size (carapace is ~297 mm long and 214 mm wide), shape, smooth shell texture, and prominent scalloping on the posterior margin of the carapace. Sulci on the plastron are not distinct, and cannot be used to refine the identification. The phalangeal formula is 2:3:3:3:3 and ?2:3:3:3:3 for the manus and pes, respectively, as seen in other turtles. These regions are poorly known in Baenidae, but as preserved in RAM 24819 broadly to match published examples. Overall phalangeal proportions are slender, and the unguals are slender and elongate. RAM 24819 provides important information on baenid limb anatomy, as well as faunal data for a poorly known exposure of the Lance Formation.





## INTERNAL ANATOMY OF A BRACHYURAN CRAB FROM A LATE CRETACEOUS METHANE SEEP AND A BRIEF OVERVIEW OF INTERNAL SOFT TISSUES IN FOSSIL DECAPOD CRUSTACEANS

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### Keywords

cold seep, Cretaceous, exceptional preservation, methane seep, soft tissue



Cretaceous-aged methane or cold seep carbonates in the Western Interior Seaway, USA, have yielded a relatively high diversity and concentration of fossils, including decapod crustaceans, compared to their surrounding co-eval sediments. With technological advances in non-destructive imaging techniques, these decapods can be studied in greater detail. Here, we present a brachyuran crab specimen from an upper Campanian methane seep carbonate in South Dakota, USA. While the external morphology of the crab is insufficient for species identification (*Secretanella* sp.), remarkable details of the internal morphology are preserved including soft tissues. Four phyllobranchiate gills are visible from the outside. A  $\mu$ CT scan revealed parts of the digestive tract such as the esophagus and the cardiac stomach but also possible anterior gastric muscles. It is the first time that an esophagus is reported in a fossil decapod. We also found mandibles and their apodemes. The preservation of soft tissues implies that this locality may now be considered a Konservat-Lagerstätte. To our knowledge, the studied crab contains the first preserved soft tissue reported from an ancient methane seep. Our new overview of internal soft tissues preserved in fossil decapod crustaceans shows that, besides muscles reported on previously, gills and parts of the digestive tract are most often reported. Reproductive organs, nerve chords, and the heart are only known from few occurrences. Despite an increase in fossil decapods with internal soft tissues preserved over the last decade helping to clarify the evolution of organs, soft internal anatomy preservation remains relatively rare with < 100 occurrences.



## THE UPPER TRIASSIC POLZBERG *KONSERVAT-LAGERSTÄTTE* — A PRECIOUS WINDOW IN THE CARNIAN PLUVIAL EPISODE

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### Keywords

*Konservat-Lagerstätte*, Palaeobiota, Carnian Pluvial Episode, Late Triassic, Austria



Triassic Palaeobiota of fossiliferous sites known as *Konservat-Lagerstätte* are precious sources of palaeobiological information providing unique insights into palaeocommunities, food chains and dietary habits of marine ecosystems. A rich marine assemblage from the lower Carnian Polzberg *Konservat-Lagerstätte* in the Northern Calcareous Alps of Austria is presented. The fossiliferous layers were deposited during the Julian 2 Ib (*Austrotrachyceras austriacum* Zone). The fine-laminated Reingraben Shales comprise abundant and well-preserved members of the marine Carnian food chain. Invertebrates with the bivalve *Halobia*, the ammonoid *Austrotrachyceras* and the coleoid *Phragmoteuthis* dominate over vertebrate actinopterygian fish. Fragile groups such as polychaetes and isopods are entirely preserved as soft body fossils. The diverse assemblage comprises ammonoids (*Austrotrachyceras*, *Paratrachyceras*, *Carnites*, *Sageceras*, *Simonyceras*), coleoids (*Phragmoteuthis*, *Lunzoteuthis*), bivalves (*Halobia*), gastropods (caenogastropods/heterobranchs), one echinoid, thylacocephalan arthropods (*Austriocaris*, *Atropicaris*), crustaceans (*Platycheila*, isopods *Obtusotelson*, *Discosalaputium*), polychaetes (*Palaeoaphrodite* sp., eunicids), acylinopterygians (*Saurichthys*, *Polzbergia*, *Peltoleptus*, *Habroichthys*), coelacanth fish ("*Coelacanthus*"), a lungfish (*Tellerodus*), and a conodont clusters (*Mosherella*). Regurgitalites produced by large durophagous fish and coprolites produced by piscivorous actinopterygians accompany the Polzberg palaeobiota along with rare plant remains (*Voltzia*). The entire fauna of Polzberg and the excellent preservation of the specimens present a window into the Upper Triassic assemblage and palaeoenvironment during the so-called Carnian Pluvial Episode (CPE) in the early Mesozoic. The Polzberg palaeobiota was deposited during the global CPE, triggering the environmental conditions of the Reifling Basin and resulting in the formation of the Reingraben Shales with the Polzberg *Konservat-Lagerstätte*. New findings allow to create a precise reconstruction of the palaeoenvironment and the trophic food web of the Polzberg palaeobiota.



## 3D RECONSTRUCTION AND MICROARCHITECTURE OF A RETICULATE BELEMNOID CEPHALIC CARTILAGE FROM THE LATE TRIASSIC POLZBERG *KONSERVAT-LAGERSTÄTTE*

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### Keywords

Belemnoids, Cephalic Cartilage, *Konservat-Lagerstätte*, Late Triassic, *Phragmoteuthis*, Austria

Hyaline cartilage is considered as a convergent trait in animal evolution. This soft tissue is widely distributed in the various invertebrate groups. As its evolution still remains enigmatic, the rare occurrences of mineralised cartilage within the fossil record are important for evolutionary biology and palaeobiology. Especially cephalopod cartilage shares histological similarities with vertebrate cartilage, such as the prominent and widely distributed channel system. In the present study, nearly 70 historical and in-situ finds from a recent excavation campaign at the late Triassic Polzberg *Konservat-Lagerstätte* near Lunz am See (Lower Austria, Northern Calcareous Alps) of carbonised fossils were measured, described and examined concerning its micro- and ultrastructure. These fossils often appear in association with belemnoid remains of *Phragmoteuthis bisinuata*. The fossils were examined by Energy Dispersive X-ray Spectroscopy (SEM-EDX), thin sectioning and microprobe. For the analysis of the internal structure, 15 selected specimens were serially sectioned. Micro-Computer tomography (Micro-CT) revealed a widely branched system of canaliculi following the cartilage-morphology. Two high-resolution Micro-CT scans permitted the measurement and distribution of the individual canals. The corresponding 3D reconstructions were particularly instructive in getting an accurate picture of the topology of this channel system. Especially the presence of reticulate cephalic cartilages, which are also known from recent oegopsid coleoids, suggests a pelagic neutrally-buoyant locomotion. Our new findings on the shape, internal structure and the position of these long-known fossil structures strengthen the theory of preserved, mineralised cephalic cartilage of the basal cephalopod *Phragmoteuthis bisinuata* in the deposits of the Polzberg *Konservat-Lagerstätte*.





## THE PLATTENKALKS OF THE CAUSSE MÉJEAN (FRANCE): A KEY LANDMARK FOR THE RECONSTRUCTION OF UPPER JURASSIC COASTAL PALAEOECOSYSTEMS

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### Keywords

Kimmeridgian-Tithonian, lithographic limestone, coastal palaeoecosystems, Causse Méjean

The excavations organized in the upper Kimmeridgian–lower Tithonian lithographic limestone of the Causse Méjean (southern France) over the last two decades revealed two exceptional palaeontological sites (Drigas and Nivoliers). Their fossil assemblages show the co-occurrence of diverse marine organisms (algae, bivalves, brachiopods, cephalopods, echinoderms, decapod crustaceans and fishes) and terrestrial taxa (plants: conifers, bennettitaleans and pteridosperms; vertebrates: rhynchocephalians). The palaeontological content and the lithological features demonstrate that the depositional environment was a calm, protected and shallow-marine environment such as a lagoon partially or occasionally open to the sea. Fossils are allochthonous to parautochthonous and document diverse ecological habitats. Based on the exquisite preservation of many specimens, the Drigas and Nivoliers quarries can be regarded as Konservat-Lagerstätten. The fine mudstone texture, the low hydrodynamic conditions, the limited transport, the presence of microbial mats preventing remains from oxidation and/or scavenging, and the rapid burial contributed to the exceptional preservation of this biota. Similarly to other famous Upper Jurassic plattenkalks of western Europe such as Solnhofen, Cerin or Canjuers, the Causse Méjean is a key landmark for our understanding of coastal/lagoonal palaeoecosystems during the Kimmeridgian–Tithonian interval.





## PHYLOGENETIC MORPHOMETRIC ANALYSIS IN AMMONOIDS

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### Keywords

Ammonoid, phylogenetic, cladistics, geometric, morphometrics

In this work, I studied the phylogenetic relationships of 17 ammonoid taxa from the López de Bertodano Formation (Antarctic Peninsula) using phylogenetic morphometrics, a method that allows the integration of geometric morphometric data into standard cladistic analyses. In this case, the ammonoid whorl profile (the contour of the whorl in a transversal cross-section of the conch) was translated to a semilandmark configuration and coded as an additional continuous character for each specimen. This dataset was then joined to a matrix containing both discrete and continuous characters, and analyzed using the software TNT V1.6 (varying the search parameters). Results allow predicting the whorl profile of the hypothetical ancestors, and it is useful to analyze the phylogenetic relationship of the studied taxa. I also review if there are evolutionary trends related to the shell size among the studied species, mapping the diameter and the centroid size in the obtained topologies. Further, an additional sensitivity analysis was performed using implied weighting to check the effect of reducing the relevance of the geometric morphometric data in the analysis. These results indicate that the geometric morphometric data sustain phylogenetic information useful for assessing the relationships of the studied species.





## IN SITU POLLEN OF VOLTZIALEAN CONIFERS FROM THE MIDDLE TRIASSIC IN CENTRAL EUROPE

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### Keywords

Palynology, Plant Fossils, Coniferophyta, Anisian, Ladinian

Conifers of the order Voltziales were important components of Triassic floras. Their pollen is likewise abundant in microfloras from this period. Voltzialean pollen grains are known to have a considerable range of appearances, but taxonomic distinctions based on these differences require thorough descriptions of *in situ* pollen from well-preserved male cones. We studied the pollen extracted from such cones hailing from the palaeofloras of the Dont Formation in Italy, the Grès à Voltzia in France (both Anisian, early Middle Triassic), and the Erfurt Formation in Germany (Ladinian, late Middle Triassic). Pollen cones from the Dont Formation contained taeniate bisaccate pollen corresponding to forms that have previously only been found in association with Palaeozoic conifers, as well as in one case multi-taeniate pollen grains resembling those commonly associated with seed ferns. By contrast, *in situ* pollen from the Grès à Voltzia and the Erfurt Formation is consistently non-taeniate. Several *Willsiostrobus*-type cones from the Erfurt Formation that are not assignable with certainty to any species yielded pollen showing differences that support assignments to various species.





## PHOTOGRAMMETRY AS A TOOL TO SUPPORT FIELDWORK ANALYSIS: A CASE STUDY IN BAJADA COLORADA (LOWER CRETACEOUS), NEUQUINA BASIN, PATAGONIA ARGENTINA

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### Keywords

Digitalization, 3D Data, Taphonomy, Photogrammetry, Sauropoda



The Bajada Colorada Formation (Berriasian-Valanginian) hosts one of the best-representative Early Cretaceous dinosaur assemblages, composed by the titanosaur *Ninjatitan zapatai*, the diplodocid *Leinkupal laticauda*, the dicraeosaurid *Bajadasaurus pronuspinax*, indeterminate theropods, such as abelisauroids and megalosaurids, as well as indeterminate thyreophoran ornithischians. Most of the specimens aforementioned come from the same quarry, mainly composed by isolated and intermixed bones and teeth. It can be challenging to associate certain fossils to a specific specimen due to the conditions of fossil accumulation, which is abundant in a restricted area. The present study is the first attempt to perform a taphonomic analysis at the site, using as a case study six sauropod caudal vertebrae found associated in a small area, few meters far from the main excavation. The photogrammetric software Agisoft Metashape (Version 1.8.4) was used to create eight 3D models representing different phases of the excavation during five days. Using photogrammetry as a field tool offers a three-dimensional image that provides better insight into the excavation site than a 2D scheme or photograph. This increases the comparative value and replicability of the analysis for other researchers unable to view the excavation site in person. Photogrammetry is intensively used in ichnology field work and similar generalizations of the use of this tool also in body fossils excavations will therefore allow greater accessibility to field data for both colleagues and reviewers, increasing the value of the resulting taphonomic studies or just supporting the skeletal association grade, for systematic purposes, in intermixed bone quarries.



## A NEW LARGE COASTAL BOTHREMYDID TURTLE FROM NIGER

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### Keywords

Maastrichtian, Late Cretaceous, Testudines, Pleurodira, Bothremydidae

The shell of a pleurodiran turtle found more than 30 years ago in Southwestern Niger, and deposited in the Natural History Museum of London, remained until now unpublished. It corresponds to an aquatic turtle of relatively large size, showing a maximum shell length of about 65 cm. Specifically, the find was made in an upper Maastrichtian outcrop of the Indamane Mount area, located in the Abalak Department of the Tahoua Region (Iullemeden Basin). It has been identified as attributable to a new member of Bothremydidae, characterized both by several autapomorphies as well as by displaying a unique combination of shell characters. Its potential attribution to the lineage of Maastrichtian to Paleocene large coastal bothremydids *Nigeremydini*, exclusively known in the African Trans-Saharan seaway, is discussed. This is done based on the information provided by both finds previously made in Niger and fossil remains from other African countries, highlighting unpublished and well-preserved complete and partial shells from Mali.





## STATE OF THE ART OF THE MOSASAURIDAE FROM MEXICO

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### Keywords

Mososauridae, Mexico



The first mosasaur record from Mexico reported in 1930, belongs to *Amphekepubis johnsoni*, from the San Felipe Formation (Coniacian), in Nuevo Leon. Subsequently, mosasaur material was described from Tamaulipas, collected from the Mendez Formation (Campanian-Maastrichtian). In 1993, mosasaur remains were reported from the Mendez Formation of Nuevo Leon, and referred to the genus *Clidastes*. *Clidastes* is also reported from Coahuila, for the Cerro del Pueblo Formation (Campanian), and isolated vertebrae and teeth have been recorded from elsewhere in the same formation. In 2013 a *Tylosaurus* skull was recorded from the Ojinaga Formation (Turonian) of Chihuahua. A Plioplatecarpinae has been reported from the Boquillas Formation (Cenomanian-Turonian), determined as *Platecarpus* aff. *planifrons* as well as material of a yaguarasaurine mosasauroid. Also from Coahuila have been recorded the presence of the genera *Prognathodon* from the Mendez Formation, *Tylosaurus* from the Eagle Ford Formation (Cenomanian-Turonian) and *Clidastes* from the Aguja Formation (Campanian), as well as isolated teeth from the Pen Formation (Santonian) have been recorded. Additional mosasaur material has been described from the Mexcala Formation (Turonian) of Puebla and from the Angostura Formation (Campanian) of Chiapas. Undescribed mosasaur material was recently found near Cerro Prieto Dam, at Nuevo Leon, from sediments of the Mendez Formation. The specimen consists of cranial fragments, vertebrae, partial pelvic remains, limb elements and ribs. Finally, a mosasaurid skull collected in the Upper Member of the Agua Nueva Formation (Turonian), in Nuevo Leon has been donated to the Museo del Desierto, and is under study. Here we provide an overview of these specimens and discuss the recently collected material.



## AN EXAMINATION OF THE PRESERVATION OF PLESIOSAURS (REPTILIA: SAUROPTERYGIA) FROM THE LATE CRETACEOUS TROPIC SHALE, SOUTHERN UTAH, U.S.A.

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### Keywords

Plesiosaur, Taphonomy, Cretaceous, marine, Tropic Shale

A rich fauna of marine life is preserved within the Late Cretaceous (Cenomanian-Turonian) Tropic Shale of southern Utah, U.S.A., including ammonites, oysters, bony fish, sharks, turtles, mosasaurs, and plesiosaurs. The Tropic Shale represents the western margin of the Cretaceous Western Interior Seaway in North America. This study includes 28 plesiosaur specimens (from the collections at the Museum of Northern Arizona). To date, five genera within two families (Polycotylidae, Pliosauridae) have been described, although the preservation of many specimens does not allow for specific identification. All specimens were discovered within fine-grained black shale, including 18 found in float (no *in situ* bone), five disarticulated, one associated, and four partially articulated skeletons. Skeletal elements display low levels of abrasion, weathering, and compression, but high levels of fracturing. Specimens found in float have slightly higher levels of abrasion and weathering, from modern processes during exposure at the surface. Fossils associated with more complete specimens range from invertebrates to isolated shark teeth to coprolites. Only one specimen contained associated gastroliths. More complete specimens commonly have scavenging marks, although there is no evidence of colonization of skeletal elements by epibionts. Geographically, specimens to the west are less abundant and more isolated, occurring in areas with geological indicators of shallower water conditions, poorer conditions for fossil preservation. The taphonomic condition of plesiosaur skeletons from the Tropic Shale confirms the paleoenvironmental reconstruction of an active water column with scavenging activity, and a quiet, low-oxygen seafloor with moderate sedimentation rates, particularly in areas of deeper water.





## ORGANIC PETROLOGY AND GEOCHEMISTRY OF THE SANTA CLARA ABAJO FORMATION, TRIASSIC, CUYANA BASIN, ARGENTINA

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### Keywords

Organic Matter, Lacustrine, Rock-Eval Pyrolysis

We present the results of visual analyses of organic matter (OM) recovered from outcrop samples of the Santa Clara Abajo Formation (SCAb) and geochemical studies of the sediment obtained. The unit belongs to the Peñasco Group, and is located in the northern Mendoza province, which form part of the Triassic infill of the Santa Clara sub-basin (Cuyana Basin). The unit is approximately 500 m thick, and corresponds to fluvio-deltaic and lacustrine deposits. Five mudstone samples representing the central areas of the lacustrine area were obtained and analyzed to provide data about the depositional environment and to evaluate their potential for hydrocarbon generation. The study included the determination of total organic carbon (TOC) content by pyrolysis, Rock Eval and OM analysis by transmitted light microscopy. Pyrolysis results showed TOC values between 1.03 and 1.84 wt%, maximum temperature of S2 peak (Pyrolysis of kerogen) between 439°-445°C, Hydrogen Index between 332 to 626 mg HC/g rock, and kerogen type defined as KI-KIII. The OM content is mainly terrestrial in origin, including palynomorphs such as pollen grains and spores (*Inaperturopollenites*, *Klausipollenites*, *Neoraistrichia*, *Platysaccus*, *Leptolepidites* and indet. striated pollen), together with biostructured, opaque and translucent phytoclasts, and abundant amorphous OM components. The combination of the visual analysis and the geochemical results suggest a dominant terrestrial contribution of MO inputs to water bodies of low stability or reduced extension, with episodic recharge, resulting in unfavorable conditions for the development of plants with higher moisture requirements. These rocks present an early thermal maturation with good generation potential.





## NEW MICROVERTEBRATE LOCALITIES IN THE MARINE PORTION OF THE MESAVERDE FORMATION (LATE CRETACEOUS, CAMPANIAN) OF THE BIGHORN BASIN, WYOMING, U.S.A.

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### Keywords

biogeography, Cretaceous, Laramidia, Mesaverde Formation, Western Interior Seaway

Historically, the Mesaverde Formation of the Bighorn Basin of Wyoming is known for its vertebrate microfossil localities in the Teapot Sandstone (Campanian, Late Cretaceous). These assemblages include an intriguing mix of freshwater, terrestrial, and marine taxa, ranging from dinosaurs to sharks to mammals to osteichthyans. During the 2022 field season, a crew from the Raymond M. Alf Museum of Paleontology (RAM) identified previously undescribed localities from much lower in section in the Mesaverde Formation, approximately 76 meters below the Teapot Sandstone. These are notable in that they are (to our knowledge) the stratigraphically lowest vertebrates known from the Mesaverde Formation in the eastern Bighorn Basin. A worn dinosaur limb bone was collected with oysters encrusting the upper surface, demonstrating an unusual faunal association with importance for environmental and taphonomic interpretations. One site (RAM V2022016) was surface collected for microvertebrate fossils, and a small sample was wet screened to test site productivity. Taxa identified to date include sharks, rhinobatoids, osteichthyan fish, turtles, crocodylians, and hadrosaurid dinosaurs. These are mixed with oyster shells in the same horizon, unlike the microvertebrate localities in the Teapot Sandstone. Common selachians include *Meristodonoides montanensis*, *Pseudodontaspis herbsti*, *Carcharias steineri*, *Archaeolamna kopingensis*, and *Scapanorhynchus texanus*. The overall assemblage, though, has a much higher abundance of marine taxa, suggesting a different paleoecological or taphonomic setting versus that in the overlying Teapot Sandstone.





## CRETACEOUS STROMATOPOROIDS AS TAPHONOMIC ENGINEERS FROM THE JANDAÍRA FORMATION (UPPER CRETACEOUS), POTIGUAR BASIN, BRAZIL

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### Keywords

Stromatoporoids, Sponges, Taphonomy, Cretaceous, Taphonomic Engineering

Taphonomic engineering refers to the influence of an organism on the preservation potential of another. It can be either destructive or constructive. Here, we present a case where a stromatoporoid-like sponge from the Late Cretaceous (Turonian - Campanian) is acting as a constructive taphonomic engineer by bioimmuration of gastropods. Those specimens (N:8; deposited at Museu Câmara Cascudo) were collected from the Potiguar Basin, Jandaíra Formation from the Mulungu outcrop, Brazil. Many of the shells from these regions show signs of recrystallization or dissolution, their increases preservation potential increased due to the action of sponges; some structures were maintained during diagenesis. Two types of gastropods were found in association with the sponges: turriculate shell forms of the Nerineidae family, which are prevalent, and a Trochoidea gastropod, still unidentified. The turriculate shells were mainly preserved by recrystallization, visible in many of the fractured pieces of sponges, showing both the tridimensional preservation and internal structures of the gastropod. On the other hand, the Trochoidea shell was mainly preserved by bioimmuration; only one specimen was recovered from the outcrop. The presence of nodular bases, spines, and a low conical spire suggested that the bioimmuration scars on sponges may have belonged to the same organism. The good preservation observed in these specimens is most likely due to the taphonomic engineering action of sponges, which altered the fossilization potential of some gastropods. Previously, this process was only described for Ordovician bryozoans that preserved many basibionts by bioimmuration. This discovery in the Cretaceous demonstrates the importance of understanding the influence of sclerobionts on basibionts' preservation.





## OXYNOTICERAS AND CHELTONIA AMMONOID GENERA (SINEMURIAN, LOWER JURASSIC) IN THE ASTURIAN AND LUSITANIAN BASINS

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### Keywords

Systematics, Ammonite, Morphological Analysis, Spain, Portugal



*Oxynoticeras* and *Cheltonia* are registered in the Oxynotum and Raricostatum zones of the Asturian (AB) and Lusitanian (LB) basins. Several authors have claimed the possible dimorphism between them, *Oxynoticeras* as macroconch and *Cheltonia* as microconch. *Oxynoticeras oxynotum* (Quenstedt) and *Cheltonia* cf. *accipitris* (J. Buckman) are recorded in both basins in the Oxynotum Zone – Oxynotum Subzone. They are found mostly in the same stratigraphic levels. *Cheltonia* cf. *accipitris* has straight ribs and the peristome is projected forward, although most specimens are preserved as crushed and smooth. They have a diameter of 8.8-27.9 mm. *O. oxynotum* has falcoid ribs and a fastigiate cross-section, it has a diameter of 29.3-216.3 mm. *Oxynoticeras lymense* (Wright) and *Cheltonia* sp. are registered in the Raricostatum Zone – Densinodulum Subzone of the LB. *O. lymense* is slightly falcoid ribbed with a bundle of striae, it has a diameter of 20.2ca.-81.1ca. mm. *Cheltonia* sp. is preserved as smooth conchs with a fastigiate ventral area, and it has a diameter of 10.7ca.-25.2ca. mm. However, although this overlapping in size, the umbilical-diameter ratio is bigger in *Cheltonia* sp. than in *O. lymense*. As well as it is bigger in the pair *O. oxynotum* – *C. cf. accipitris* than in *O. lymense* – *Cheltonia* sp. *O. lymense* has been also described in other localities of NW Europe, but without the presence of *Cheltonia* in the same stratigraphic levels so far. In the LB, the joint presence of both genera supports the hypothesis of a dimorphic relationship between them and an evolutionary trend toward involution.



## EARLY TRIASSIC CONODONT-BEARING BROMALITES FROM SOUTH CHINA

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### Keywords

bromalites, predation, food web, Lagerstätte, Smithian

The incompleteness of the fossil record limits our knowledge of extinct organisms and how they interacted in ancient communities. However, bromalites (fossilized remains of digestive matter) provide unique insights into palaeoecology, especially concerning aspects such as diets and trophic interactions. Here, abundant bromalites preserved as flattened films or impressions are reported from the latest Smithian (Olenekian, Early Triassic) at Longtan locality, Jiangsu Province, China. A total of 52 well-preserved specimens are categorized into six morphotypes, of which the majority of specimens (67.3 %) contain numerous conodont elements, including the characteristic species *Scythogondolella milleri*. Based on the morphology, inclusions and geochemical signatures, three morphotypes are ascribed to be coprolites with carbonaceous or phosphorous matrix while the other morphotypes are interpreted as regurgitalites with a paucity of the matrix. The conodont-bearing bromalites were likely produced by ammonoids, crustaceans and carnivorous coelacanths, according to integrative indicators. These bromalites provide behavioural data (e.g., predation, scavenging and vomiting) on multiple Early Triassic taxa. The preponderance of conodont-bearing faeces and regurgitations evidences that multiple predators, invertebrates and vertebrates, fed on conodonts in this Early Triassic ecosystem. Combined with body fossils, the Longtan bromalites are suggestive of complex food web networks in the Smithian community. Furthermore, the co-occurrence of flimsy bromalites and exceptional-preserved conodont natural assemblages probably suggests an end-Smithian Konservat-Lagerstätte.





**Herpetofauna of the Early Miocene locality  
of les Cases de La Valenciana 1 (Vallès-  
Penedès Basin, Iberian Peninsula)**

Gamarra González Jesús  
Palaeoart Competition (1<sup>st</sup> Prize)

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**Cenozoic**



**General Session**



## PALAEOENVIRONMENTAL CHANGES OF THE LATE MIOCENE PUERTO MADRYN FORMATION (PENÍNSULA VALDÉS, ARGENTINA) DETECTED USING SEDIMENTOLOGICAL, PALAEONTOLOGICAL AND ICHNOLOGICAL APPROACHES

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### Keywords

Chubut, Late Miocene, Diatoms, Invertebrates, Ichnology

The aim of this study is to reconstruct the palaeoenvironmental evolution of the lower part of the Late Miocene Puerto Madryn Formation at Punta Buenos Aires (NE Patagonia, Argentina) by integrating sedimentology, fossil diatoms, macroinvertebrates, and ichnology. The 45m-thick sedimentary section was divided into eight intervals separated by different types of stratigraphic surfaces. Marine fossils are abundant and diverse in shoreface to offshore deposits, while two intervals are barren of fossils, and are interpreted as prodelta and estuarine deposits. Different groups of bivalves dominated by pectinids and oysters, together with bryozoans, brachiopods, and gastropods are documented in sand-prone deposits, along with an ichnological association dominated by *Helicodromites*, *Ophiomorpha*, *Taenidium*, *Teichichnus*, and *Thalassinoides*, indicating moderate-energy shoreface environments. In contrast, mudstone deposits characterized by *Panopea* in life position and abundant *Chondrites*, suggest lower-energy, offshore environments. At the top of the section, reworked shell fragments, together with *Thalassinoides* and *Skolithos* in cross-bedded sandstones, suggest tidal channel deposits. Diatom assemblages are dominated by *Paralia sulcata*, with the exception of one sample dominated by the marine genus *Pseudopodosira*. *P. sulcata* indicates accumulation in coastal marine environments, whereas *Pseudopodosira* might be reflecting a deeper (offshore) environment. All data indicate that the studied deposits accumulated in a wide range of palaeoenvironments, suggesting the occurrence of several relative sea-level variations. It is still unclear why the diatom composition remains unchanged along so different palaeoenvironments as well as what factors provoked the intercalation of fossil-barren prodelta deposits within a fossil rich and diverse succession.





## NEW DISCOVERIES ABOUT FOSSIL FRESHWATER CRAYFISHES

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### Keywords

Astacoidea, Crustacea, Slovenia, Czech Republic, Decapoda

Freshwater crayfishes are among the largest and most successful freshwater invertebrates: they are spread worldwide, have marked impacts in the environment they inhabit naturally or have been introduced to. Yet, we do not know much about their evolutionary history: when they appeared, and how they evolved, spread, and ultimately reached the biogeographic distribution and diversity of present times. One of the problems with freshwater crayfish fossil record — as with most other crustaceans — is that once described, fossil species are rarely revised in the light of advances made on extant species. In practice, a fossil species assigned to *Astacus*, depending when it was described can be any lobster-like crustacean, as seen with *A. multicavatus* Bell, 1863, or a crayfish of another genus, as seen with *A. edwardsi* Van Straelen, 1928 (now placed in *Emplastron*). The other issue with the fossil record of crayfish is its paucity: only around 30 occurrences are known since Triassic, compared to over 600 extant species. In the communication, we report the recent description of a new, well-preserved, fossil crayfish from the Upper Miocene of Slovenia and how our reinvestigation of fossils assigned to *Astacus* from Czech Republic have shown they are actually marine decapods.





## LATE MIOCENE PALAEHOPLOPHORINI (XENARTHRA, GLYPTODONTIDAE) FROM THE PUERTO MADRYN FORMATION (CHUBUT, ARGENTINA): DIVERSITY AND BIOCHRONOLOGICAL IMPLICATIONS

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### Keywords

Diversity, Glyptodonts, Miocene, Neogene, Taxonomy

The Palaehoplophorini are a poorly known tribe of glyptodonts that appeared during the Middle Miocene of Patagonia (Argentina) after a diversity decline of the Propalaehoplophorinae. Their diversity was low with respect to other glyptodont groups and includes just two well-characterized taxa from Patagonia, *Palaehoplophorus meridionalis* and *Palaehoplophoroides rothi* (Middle Miocene, ca. 12 Ma). Putative Late Miocene Palaehoplophorini, such as *Palaehoplophorus antiquus* and *Aspidocalyptus castroi*, are defined from very fragmentary materials, without relevant diagnostic characters at tribe and specific level. Additionally, contrary to previous studies, a recent revision of Late Miocene (ca. 9 Ma, Chasicoan Stage/Age) glyptodonts from central Argentina confirmed the absence of representatives of this tribe. Here, we describe several Palaehoplophorini remains coming from the upper levels of the Puerto Madryn Formation in Península Valdés (Chubut Province, Argentina) assigned to the Late Miocene (ca. 9.4 Ma). Materials include carapace osteoderms, caudal rings and tube fragments, and an associated right femur (PA-09-11/10-11/11-11/12-11/13-01/MPEF-PV2531/2532/AC12FS/AC5FS1-4), which are assigned to Palaehoplophorini for having osteoderms bearing a double row of peripheral figures of irregular outline (inner row figures being smaller than the outer ones) and conspicuous dorsal foramina surrounding the central figure. The femur, one-third larger than that of *Kelenkura castroi* from the Chasicoan Stage/Age, implies a body mass exceeding 160 kg. These materials confirm the presence of Palaehoplophorini during the Late Miocene, at least in Patagonia. Further comparisons with other putative Palaehoplophorini remains from outside Patagonia (*i.e.*, Ituzaingó Formation, Entre Ríos, Argentina) will show whether or not it is a tribe restricted to Patagonia.

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## **OPHIOMORPHA-PARAHAEANTZSCHELINIA ICHTNOFABRIC FROM THE LOWER PLIOCENE OF LEPE (HUELVA, SW SPAIN)**

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### **Keywords**

Ichnology, Bioturbation, Ichnofabric analysis, Pliocene, Lepe

A new urban outcrop from the lower Pliocene of Lepe (Huelva, SW Spain) is preliminarily described herein. The reduced outcrop, with an exposed stratigraphic section of approximately 4 m thick, is composed of several units characterized by ichnofabrics dominated by *Ophiomorpha nodosa*. From bottom to top, they are: Unit 1) 90 cm of ripple cross-laminated, fine- to medium-grained sand with intercalations of centimetric microconglomerate layers. A monoichnospecific *O. nodosa* ichnofabric (ii1/2) characterizes this unit. Unit 2) 80 cm of fine- to medium-grained sand characterized by an *O. nodosa* ichnofabric (ii3) with at least two layers with abundant specimens of *Parahaentzschelinia* isp. preserved as full reliefs. Unit 3) An erosively based bed of carbonate-cemented, medium-grained sand (30 cm thick) rich in *Mytilus* sp. remains. Additionally, a layer with abundant *Macaronichnus* isp. is also observable. Unit 4) A 10 cm-thick microconglomerate layer. Unit 5) 80 cm of cross-laminated and medium-grained sand rich in mollusks with an *O. nodosa* ichnofabric (ii2/3). *Ophiomorpha* is up to 4 cm in diameter and with thick pelleted linings (up to 8-9 mm); these burrows are commonly passively filled by microconglomerate from the upper unit 6, and some of them may penetrate the underlying units 4 and 3, reaching unit 2. Unit 6) 70 cm of microconglomerate with ostreid remains and rare *Thalassinoides*-like structures. The paleoenvironmental and depositional conditions inferred for this new section point to an estuarine setting with tidal and fluvial influence, which is consistent with previous interpretations for equivalent Pliocene outcrops from Lepe area.





## NON-MARINE PLIOCENE MICROFOSSILS FROM THE ALGERIAN NORTH ORIENTAL SAHARA: PRELIMINARY RESULTS AND PALEOENVIRONMENTAL IMPLICATIONS

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### Keywords

Ostracoda, Foraminifera, Charophytes, Pliocene, Touggourt

This study shows the first record of non-marine Pliocene microfossils (charophytes, ostracods and foraminifera) from Touggourt area, north oriental Sahara, Algeria. The analysed section is located in the quarry of Beldit Omer, southern Touggourt city, which is composed exclusively of clay and fine-grained sand alternation. The genera of ostracods found were represented by *Cyprideis*, *Paracypris*, *Cytherella*, *Bradleya*, *Xestoleberis* and *Loxoconcha*, while the foraminifera correspond to the genera *Bolivina*, *Bulimina*, *Siphonina*, *Textularia*, *Globigerina*, *Globigerinoides* and *Orbulina*. In addition, the Charophytes were represented mainly by at least 4 well-preserved species belonging to *Gyrogonites*, which were documented for the first time in this region: *Chara vulgaris*, *C. globularis*, *Chara* sp. and *Nitellopsis globula*, some of them are corticated type. Furthermore, our finding includes aquatic gastropods associated with the reported microfossils. These microfossil assemblages suggest a shallow lacustrine waters as well as the Neogene deposits neighboring regions. They offer significant information about the paleoecological conditions prevailing in the Basin of Touggourt (stable, oligotrophic and oligohaline environment).





## HOW OLD IS THE HUMBOLDT CURRENT SYSTEM?

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### Keywords

Upwelling, Primary production, Peru, Pisco Basin, Pacific Ocean

Nowadays, about 20% of the world's marine fish catch comes from the Peru-Chile area in the southeastern Pacific Ocean. The high productivity and biomass abundance of these waters reflect coastal upwelling in the framework of the Humboldt Current System (HCS). The latter includes surface and subsurface currents that bring deep, cold, nutrient-rich waters from Antarctica to Peru. Despite its ecological significance, the age and origin of the HCS remain poorly constrained. Here, we present a comprehensive review of previous works on the deep past of the HCS and coastal upwelling off Peru, with a special focus on the Cenozoic succession of the southern Peruvian Pisco Basin. The Paleogene biogenic portion of the basin fill indicates warm-water conditions for the middle Eocene and an incipit of coastal upwelling before the latest Eocene, hinting at the existence of a "proto-Humboldt current". A late Eocene age is also attributed to the establishment of the Antarctic Circumpolar Current following the opening of the Drake Passage and Tasmanian Gateway. Although diatomaceous sediments have occurred since the late Eocene, the main diatom genera indicate seasonal rather than year-round upwelling. Warm/temperate taxa in the Lower-Middle Miocene, and paleotemperature estimates as well as diatom assemblages in the Upper Miocene point to a moderate upwelling during the Early-Middle Miocene that strengthened in Late Miocene times. Likewise, neodymium isotope ratios of fossil shark teeth show an overall Miocene-Pleistocene trend similar to that of the deep equatorial Pacific, with increasing contribution of Antarctic waters since ca. 6 Ma.





## PLIOCENE FISHES OF THE FAMILY GOODEIDAE FROM THE AMAJAC PALEOLAKE (HIDALGO, MEXICO)

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### Keywords

Goodeids, Pliocene, fossil fishes, Mexico, endemic

Goodeids are relevant in Mexico due their viviparity and because the Goodeinae subfamily is endemic of Mexico. This family arose in the early Miocene; however, the fossil record is scarce and poorly preserved, which represents a challenge in determining their taxonomy. Currently, two fossils of extinct goodeid species have been described: *Empetrichthys erdisi* from the Pliocene deposits in California, USA; and *Tapatia occidentalis* from the Miocene lacustrine in Jalisco, Mexico. Here, we present two goodeid fossils gen. and sp. nov. recovered from the Pliocene deposits of the Paleolake Amajac, Hidalgo, Mexico. The osteological description supports their inclusion into the Goodeidae family through the presence of diagnostic features such as a maxilla with a straight distal end and a reduced premaxillary ascending process. Also, both new species share features related to the viviparity of the Goodeinae subfamily, like the presence of an andropodium in the males and the remains of unborn individuals in some females. Even with this data, is not possible to place them in any known tribe, due show features not previously reported, e.g., the presence of a posttemporal bone with a small anteroventral process in species 1 and lack of pelvic process in species 2. Species 1 seems to be closely related to *Characodon* as both share an articular facet for the quadrate as a donut-like structure, in which the retroarticular forms the central part; while species 2 shares with *Goodea* a dorsal process of anguloarticular, strongly projected backward. The discovery of these extinct goodeids on the eastern Mexican slope represents a new historical element to be considered in future efforts to understand the history of this endemic fish clade.





## NEW PLANT RECORDS BASED ON MIOCENE WOOD FROM COSTA RICA

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### Keywords

Wood anatomy, Costa Rica, Neotropics, Miocene, dry tropics

The Central American fossil record is crucial for comprehensively understanding the Neotropical Flora. It contains elements from the south that crossed to the north, or vice versa, allowing today the recognition of this flora. Historical detail of the vegetation of Central America needs to be better known, but some data exists on El Salvador and Costa Rica. We present woods from the Miocene of Costa Rica (Tivives, Esterillos ("Jacó"), Sonzapote de La Cruz, Líbano de Tilarán, Río Pataste, Monterrey, San Carlos, Puente La Muerte/Pataste, Lignito de San Rafael de Puriscal) that together recall some dry tropical vegetation. Common characteristics include the median diameter of vessel elements, 100 to 200  $\mu\text{m}$ , small to medium size alternate intervacular pits, relatively thin, slightly heterogeneous rays, 1 - 3 cells thick, and procumbent cells dominance, vasicentric and thin-banded axial parenchyma, thin-walled fibers and presence of few gums and tyloses. Variation in these characteristics suggests the presence of members of the Sapotaceae (cf. *Vitellaria*), Leguminosae (cf. *Aphanocalyx*), Malvaceae/Sterculioidae (cf. *Cola*), Myrtaceae (cf. *Eucalyptus*), and Salicaceae (cf. *Salix*). Most of these families have been reported from North and South America. Thus, the timing of arrival and biogeographic histories of the new taxa are essential to discuss further the source and assemblage of today's Neotropical Flora. The new records strongly suggest that its history is far more complicated than the simple movements in relatively recent times of the southern and northern floras to generate a new type of tropical assemblage, the Neotropical Flora.





## ANALYSIS OF BIOCLASTIC LEVELS IN A MARINE CORE NEAR VILLA GESELL PORT IN BUENOS AIRES PROVINCE, ARGENTINA

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### Keywords

Marine core, Mollusks, Holocene, Buenos Aires

The marine core was obtained by Austral Oceanographic ship with a piston engine of Ewing type during the Litoral Bonaerense II campaign carried up in December 1992. This core was recovered in marine platform with a 69.5 m length and 68 m depth near Villa Gesell Port (38° 16' 12" S/57° 1' 48" W) with six levels among which three bioclastic levels (F, D, and B). The F level (62 – 53 cm) is a mixture of medium sand to clay with marine species: *Spisula* sp. (bivalvia), *Turbonilla paralamilata* and *Natica isabelleana* (gastropods). The D level (50 – 46 cm) is composed by medium sand with *Spisula* and *Corbula lyoni* (bivalvia). The B level (42 cm – 9 cm) is composed by clayey silt sand with: *Ennucula nucleus*, *Spisula isabelleana*, *C. lyoni* (bivalves), and *Tegula patagónica*, *Bostrycaptulis odites*, *N. isabelleana*, *Zidona dufresnei*, *Olivancillaria carcellesi*, *T. paramilata* and *Anachis isabellei* (gastropods) with two genera: *Brachidontes* sp. and *Macoma* sp. (bivalves). Most bivalves and gastropods are euryhaline, infaunal bivalves with epifaunal gastropods. All of mollusks are sandy substrates with except *Brachidontes* sp., *T. patagonica* and *B. odites*. All bivalves and gastropods live between 0 – 200 m depth. The lithology, grain size and taphonomy of the bioclastic levels suggest that they are storm deposits of the Holocene age, based on the abundance of *Spisula* sp. and the marine benthonic mollusks. These levels would be correlated with the littoral deposits of the Marine Isotopic Stage 1 age found along coasts of Buenos Aires.





## EVOLUTION ENGRAVES ON OTOLITHS: USING SCIAENID FOSSIL OTOLITHS TO REVEAL THE MORPHOLOGICAL CHANGE THROUGH TIME

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### Keywords

Fossil Otolith, Sciaenidae, Landmark-Based Geometric Morphometrics, Morphological Changes

Fossil record often reveals innovations of structures after geological events, but the relationship between these morphological changes and the events that trigger them is not well understood. Fish otoliths, which belong to a fish's sensory system and can be fossilized, are prominent in fish fossils because of their high resolution in taxon-specific morphology. In this study, we investigated the evolution of otolith morphology in Sciaenidae, a fish family with rich fossil records globally, with an aim to understand how fossil otoliths of the Sciaenidae have evolved with time. By using landmark-based Geometric morphometrics (GM) and Procrustes-Principal Component Analysis (PCA), we analyzed 84 fossil species within 57 genera ( $n=100$ ), ranging from the middle Eocene (~47 Ma) to the late Pleistocene. Our results show that the morphology of global fossil sciaenid otoliths changes gradually from the Middle Eocene to the Pliocene and then diversifies drastically in the Pleistocene.





## THE EXTINCT NAUTILOID *ATURIA* FROM THE MIDDLE MIOCENE OF PACIFIC SOUTH AMERICA

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### Keywords

Aturiidae, Cephalopoda, East Pisco Basin, Langhian–Serravallian, Pisco Formation

We report on an aturiid (Cephalopoda: Nautiloidea) shell from the Pisco Formation, a Neogene marine sedimentary unit of the East Pisco Basin (southern Peru) that is broadly renowned for its rich and exquisitely preserved marine vertebrate fossil content, including an outstanding cetacean assemblage. This specimen was collected from Middle Miocene strata exposed in the vicinity of Cerro Submarino. It consists of an internal mould of a phragmocone and is tentatively identified herein as belonging to the widespread, long-ranging species *Aturia cubaensis*. This fossil represents the first occurrence of *Aturia* in the Middle Miocene of the Pacific margin of South America, and as such, it fills a gap in the chronostratigraphic distribution of the Southeastern Pacific finds of this genus, helping to bridge the Lower and Upper Miocene segments of its regional fossil record. The rarity of *Aturia* in the shelfal Cenozoic deposits of the East Pisco Basin may reflect the palaeoenvironmental habits of this extinct cephalopod genus, which may have lived in the upper bathyal zone, at about 250–350 m water depth. Despite some recent suggestions that some extinct and extant marine mammal ecomorphotypes (including some odontocetes) were likely predators of nautiloids, there is no indication that any member of the diverse and abundant toothed whale faunas of the Pisco Formation exploited these shelled cephalopods as a relevant food source.





## EVOLUTION OF HYPSONDONTY, BODY MASS, ENAMEL COMPLEXITY AND OCCLUSAL SURFACE AREA IN TOXODONTIA

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### Keywords

Notoungulata, Hypsodonty, Body mass, Fractals, Ecomorphology

Toxodontia comprise an herbivorous extinct ungulate clade native to South America, ranging from small-sized forms to megamammals. Some features, such as body mass (BM), hypsodonty index (HI), occlusal surface area (OSA), and enamel crown complexity (ECC), vary during the evolutionary history of Toxodontia, but their interrelationships remain poorly understood. In this work, complete and incomplete mandibles of 253 specimens were used to estimate BM (65 species) and dental features for 58 species. Mandibular and tooth linear measurements, as well as area (OSA) and fractal dimension (ECC), were obtained using ImageJ software on digital images. BM was estimated using allometric equations for extant ungulates available in the literature. Quantile regression against the date of first and last appearance and a reconstruction of quantitative ancestral characters were performed. The results show an increase in HI and BM, and a decrease in ECC from the basal lineages to more derived Toxodontia. In contrast, OSA does not present a relationship with geological ages or phylogenetic structure, but scales with BM. This suggests that the evolution of hypsodonty in Toxodontia is accompanied by a process of simplification in the occlusal pattern of m3 and an increase in BM, but it is still not clear how OSA covaries with other dental features. These changes reflect greater teeth durability related to abrasive consumption over greater efficiency in chewing grinding in derived and basal taxa respectively. These dental adaptations could be related to changes in habitat and/or diets, associated to increasing body mass, in agreement with classical hypothesis/works.

\*Contributions to PIP-CONICET-3036; PICT-2020-03591.





## DESCRIPTION OF AN EXCEPTIONALLY PRESERVED JUVENILE OF *GLYPTODON RETICULATUS* OWEN (CINGULATA, GLYPTODONTIDAE) FROM THE LATE PLEISTOCENE OF TARIJA VALLEY (BOLIVIA)

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### Keywords

*Glyptodon*, juvenile, Tarija allometric, ontogeny

Glyptodontinae (one of the best studied Glyptodontidae) include: *Boreostemma*, *Glyptotherium* and *Glyptodon*, this latter (*Glyptodon*) with three species (*G. jatunkhirkhi*, *G. munizi* and *G. reticulatus*). *Glyptodon* stands out for the highest frequency of South America Pleistocene records, including the most complete ontogenetic series, although many aspects of their biology are still unknown, especially those regarding allometric changes around their cranium-mandibular development. Current evidence indicates that their cranium-mandibular morphology in early development stages is allometrically different from ones of adult individuals of the same species. This early morphology has been correlated with osteoderms that have an immature ornamentation (*i.e.*, poorly or non-developed peripheral figures and principal and radial sulci and central figures with concave exposed surface). The present contribution focuses on analyzing the allometric differences between a juvenile (MNPA-V-005989) recorded in the Pleistocene of Tarija Valley (Bolivia) and adults of *G. reticulatus*, at cranium-mandibular level. The most interesting differences are at level of the post-orbital narrowing (narrower in juvenile), the relative dorso-ventral length of the descending processes of the zygomatic arch (lesser in juvenile), the development of the sagittal and nuchal crests (less developed in juvenile), the antero-posterior length of the each molariform, both maxillary and mandibular (shorter in juvenile), trilobation grade in the first molariform both, in both maxillary and mandibular (lesser developed in juvenile) and the antero-posterior length of the ascending ramus of the mandible, at the occlusal surface level (shorter in juvenile) and the height of the mandible at the horizontal ramus level (shorter in juvenile).





## A NEW SPECIES OF *PANOCHTHUS* BURMEISTER (CINGULATA, GLYPTODONTIDAE) FROM THE LATE PLEISTOCENE OF TARIJA VALLEY AND POTOSÍ, BOLIVIA

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### Keywords

*Panochthus*, Tarija Valley, Potosí, Bolivia

One of the most diversified and widely distributed lineages of glyptodonts during the Pleistocene of South America is *Panochthus* Burmeister, which includes eight species (*i.e.*, *P. tuberculatus*, *P. frenzelianus*, *P. intermedius*, *P. subintermedius*, *P. jaguaribensis*, *P. greslebini*, *P. hipsilis* and *P. florensis*) with records in the current territories of Argentina, Uruguay, Brazil, Perú, and Bolivia (from 47° 01'S and 67° 14'W to 05° 11'S and 39° 17'W). Recent studies show that the evolutionary history of this genus was complex, especially in high altitude areas, with two species recognized in the last years (*P. hipsilis* from highlands of Bolivia, and *P. florensis* from lowlands of Argentina). Here we report a new species of *Panochthus* from Bolivia with records from the late Pleistocene of Tarija Valley (MNPA-V/006920) and the area around Potosí (UATF n/n). The most important cranial characters that distinguish the species from other *Panochthus* spp. are (in lateral view): dorsal profile of the nasals concave, lateral nasal notch absent, dorso-ventral diameter of the nasal opening and dorso-ventral diameter of the skull smaller, orbital notch proportionally larger and, simple first molariform; dorsal carapace characters include (MNPA-V/006920, UATF n/n): smaller dorso-ventral diameter, highest diameter located at the midpoint, ornamentation pattern of the osteoderms with a central figure surrounded by small polygonal figures along most of the exposed surface of the carapace; cephalic shield (MNPA-V/006920) with three rows of middle osteoderms (5-3-2 in number). This report increases the diversity of *Panochthus* in high altitude areas.





## LINGULIDE BRACHIOPODS AS COMMON FOSSILS IN TUSCAN PLIOCENE DEPOSITS: NEW OCCURRENCE DATA, WITH SOME NOTES ON THE NEOGENE BIOGEOGRAPHY OF LINGULIDES

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### Keywords

*Glottidia*, *Lingula*, Lingulidae, Pliocene, Tuscany

Fossil lingulides have lately been encountered commonly in Pliocene outcrops of Tuscany (central Italy). Some relatively well-preserved specimens are here reported from four localities in the Provinces of Florence and Pisa, namely, Castelfiorentino, San Miniato, Spicchio and San Martino a Maiano. At all these outcrops, the lingulide-bearing deposits consist of coastal-marine (mostly shoreface) sandstones. In most localities, the lingulide remains characterize precise stratigraphic levels. The presence of septate as well as non-septate shells suggests that the collected material includes both *Glottidia* and *Lingula*. The presence of *Glottidia*-like specimens in the Tuscan Pliocene represents a novel occurrence datum for Italy as well as for the entire Mediterranean region. Whereas *Lingula* is present in some Miocene brachiopod assemblages of the Mediterranean Sea and Central Paratethys, the sole published records of the currently trans-Panamian genus *Glottidia* from the Eastern side of the Atlantic Ocean come from the Miocene and Pliocene deposits of the North Sea. Therefore, the newly reported occurrences of both *Lingula* and *Glottidia* at closely located sites in the central Mediterranean Basin during the Pliocene indicate that our current understanding of the palaeobiogeographic history and affinities of the late Neogene Euro-Mediterranean lingulides needs to be revised.





## CONTROLS ON PRESERVATION OF STROMATOLITES FROM EXTREME ALKALINE ENVIRONMENTS (LAKE ASHENGE, TIGRAY, ETHIOPIA)

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### Keywords

Carbonate, Mg-Silicate, Microbialite, Cyanobacteria Sheath, Organomineralization

Lake Ashenge is a modern extreme environment characterised by highly alkaline conditions (pH ~8.8; conductivity ~1600  $\mu\text{S cm}^{-1}$ ), located in the East African Rift Valley, in Tigray Region, Ethiopia. Certain types of microorganisms, including photoautotrophs, can survive and thrive in such extreme conditions, often forming stromatolites, which correspond to laminated organosedimentary structures generated by the interaction of microbial communities with chemical and trapped sediments. We characterized the microfacies of stromatolites from Lake Ashenge seeking to understand their preservational processes, to provide novel information about the development of stromatolites in extreme environments with potential utility as an analogue for the astrobiological investigation of Martian palaeolakes. Both columnar and bulbous stromatolite morphologies, observed in the samples, feature slightly laminated microfabrics composed of intercalated layers of micritic calcite and microsparite. Filamentous structures and cyanobacterial sheaths were recognized in addition to the widespread presence of exopolymeric substances. Micrite laminae did not preserve the filamentous structures as much and show a dense and more homogeneous matrix of smooth crystals. Differently, the microsparite laminae showed greater efficiency in the preservation of microbial content, especially the cyanobacteria sheaths, forming palisade texture. Mg-silicates were identified in association with the carbonaceous matter remains and infilling the cyanobacterial sheaths, increasing the preservation of those structures. The source of Mg-silicates was the volcanic basement of the lake that provided an input of this material during early diagenesis. In this way, Lake Ashenge stromatolites demonstrated being a remarkable example of early diagenetic process acting on stromatolite preservation in lacustrine alkaline environments.





## THE EARLY PLEISTOCENE FAUNA OF PORTUGAL: AN UPDATED OVERVIEW

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### Keywords

Iberian Peninsula, Algoz, Morgadinho, Santa Margarida, Mammals



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The Iberian Peninsula possesses one of the best records of Early Pleistocene faunas in Western Eurasia, with localities of global importance such as Atapuerca or Orce. Nevertheless, the westernmost part of Iberia, is almost devoid of coeval localities. Three sites are known for the Early Pleistocene in Portugal; all of them from its southernmost part, in the region of Algarve: Algoz, Morgadinho and Santa Margarida. Among them, Algoz (Silves) is the best studied locality, with a fauna including two different sized species of cervids; lagomorphs, represented by just two metapodials; and *Hippopotamus antiquus*, represented by several limb fragments which have been recently revised and compared to other European hippopotamuses. The site of Morgadinho (Tavira) is characterized by its limnic microfauna, including invertebrates such as ostracods. Yet, a few and very fragmentary vertebrate remains have been found, like fish, rodents and insectivores. Unfortunately, the whereabouts of this material are currently unknown. The most recently discovered site is Santa Margarida (Loulé), a karstic infilling with thousands of microvertebrate bones forming a bone breccia. The arvicolines such as *Microtus huescarensis* and *Allophaiomys chalinei* point towards an Early Pleistocene age for at least part of the deposit, although the particular nature of the site might point out that a long time period is represented there. Further study of the fauna from these sites will allow to better constrain their age and place them on a wider Iberian context after their correlation with the rich and well-studied Spanish sites.



## PALEOENVIRONMENTAL RECONSTRUCTION OF A NEOGENE DIATOMITE FROM NORTHERN PATAGONIA, ARGENTINA

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### Keywords

Diatomite, Diatoms, Paleoenvironmental Reconstruction, North Patagonia, Neogene

Diatomite deposits are siliceous biogenic sedimentary rocks composed mainly of diatoms. Paleoenvironmental reconstruction of them are scarce in Argentina. Micropaleontological and sedimentological characterization of a Plio-Pleistocene site of La Pampa (Puelén) is presented. The aim is identifying the diversity of fossil diatoms and the paleoenvironmental evolution based on diatom assemblages' composition. The "Dique" site (Fm. El Sauzal/Tehuelche, 38°08'40.5" S; 67°09'23.2" W) presents an outcropping section of 4.20m with laminated white diatomite and three levels of volcanic ash. Seven samples 50 cm-equidistant were extracted and oxidized with H<sub>2</sub>O<sub>2</sub> for diatomological analysis. 500 valves per slide were counted in order to calculate the relative frequency of each species. Diatom zones were defined using multivariate analysis of clustering (CONISS). Diverse assemblages with at least 73 morphospecies were determined, 34 of these have abundances > 4%. Dominant and ubiquity small fragilarioid diatoms (*Punctastriata* spp., *Staurosira* spp., *Staurosirella* spp., *Pseudostaurosira* spp., among others), are accompanied by *Rhopalodia* spp., *Aulacoseira* spp., *Cymbella* spp., *Epithemia adnata* and *Cocconeis placentula*, indicating a lacustrine origin. Based on this new micropaleontological evidence, in the basal section it was inferred that a paleolake with a relatively alkaline pH, low concentrations of nitrogen and high concentrations of phosphates (volcanic ash) favored the growth of a diverse diatom community (with epiphytes, planktonic, tychoplanktonic and benthic lifeforms). Towards the top, the dominance of small fragilarioids (tychoplanktonic, brackish-freshwater species) and the decrease of all freshwater planktonic diatoms would indicate the shallowing of the water body and an increase in salinity, associated with periods of aridization.





# GEOMETRIC MORPHOMETRIC ANALYSIS OF THE DISTAL HUMERUS OF MIOCENE PRIMATES AND ITS RELATIONSHIP TO LOCOMOTION

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## Keywords

Miocene Apes, Shape Analysis, Elbow, Positional Repertoires, Catarrhine Primates

During the Miocene (23 – 5 Ma), catarrhine primates underwent a great diversification and radiation throughout Eurasia. Despite their ever-growing fossil record, which includes numerous postcranial elements, several aspects of catarrhine paleobiology are still not well understood and are not exempt of disparate opinions among researchers, such as their locomotor repertoires. Here, we studied the morphology of the distal humerus (trochlea, capitulum, and the whole distal end separately) of several key Middle-Late Miocene primates, including: *Ekembo heseloni* (KNM-RU 2036 AK), *Dendropithecus macinnesi* (KNM-RU 2097), *Simiolus enjessi* (KNM-MO 17022A and KNM-WK-17009A), *Epipliopithecus vindobonensis* (individual II) and *Sivapithecus indicus* (GSP 30730). Morphology was quantitatively compared with 144 extant individuals and 2 fossil non-Miocene anthropoids using landmark-based 3D geometric morphometrics. Computations of Blomberg's K and Pagel's  $\lambda$  indicate that distal humeral shape embeds high phylogenetic signal ( $K > 1$ ;  $\lambda \approx 1$ ). Morphometric analyses of the whole epiphysis and trochlea enable good discrimination between extant hominoids and other (extant and non-Miocene fossil) anthropoids, unlike those based on capitulum shape alone. Regarding the fossils, the distal humerus of both *Epipliopithecus* and *Dendropithecus* showed morphological affinities to the arboreal suspensory/climbing atelids (such as *Ateles* and *Lagothrix*), whereas *Simiolus* showed affinities to non-suspending agile arboreal quadrupeds (like *Cebus*). Finally, *Ekembo* and *Sivapithecus* display more derived (hominoid-like) morphologies in their distal humerus than the smaller stem catarrhines. This latter finding further supports the notion that both Miocene apes are functionally related to arboreal quadrupedalism with enhanced mobility in the limbs and increased prehensile capabilities in the hands.





## CHEEK TEETH CHARACTERIZATION IN *PYROTHERIUM* (MAMMALIA: PYROTHERIA)

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### Keywords

SANU, Pyrotheriidae, teeth morphology, Paleogene, Oligocene

Pyrotheria is an order of Native Ungulates of South America exclusive to the Paleogene, with *Pyrotherium* as the best-represented genus from the Late Oligocene. It is known by a few skulls and mandibles, and a dental formula: I2/1, C0/0, P3/2, M3/3; however, the published descriptions of its teeth morphology are not sufficiently diagnostic. The objective of this work is to provide a better characterization of the dentition of *Pyrotherium* to differentiate upper from lower isolated cheek teeth and premolars from molars. A total of nine dental series belonging to the Museo Argentino de Ciencias Naturales “Bernardino Rivadavia”, Museo de La Plata, and Museo Paleontológico “Egidio Feruglio” were studied in detail. 1) P2 and p3 have a triangular contour, P2 has conspicuous cusps, while p3 presents three well-formed lophids; in turn, P3-M3 and p4-m3 are fully bilophodont; 2) upper cheek teeth differ from the lower by a thin and occlusally straight anterior cingulum vs an expanded and occlusally curved posterior cingulid (m3 has a well-developed posterior heel); and 3) premolars distinguish from molars essentially by size: width ratio between anterior and posterior lophs, WRAP, differentiates P3 (WRAP <1) from M1-M3 (WRAP ≥1), and anteroposterior length (L) distinguishes P4 (L ≤ 49 mm) from M2 and M3 (L ≥ 60 mm); while the posterior lophid widens from p4 to m3. In this study, we recognize distinctive characteristics for *Pyrotherium* teeth that allow us differentiate the upper/lower cheek teeth series, premolars from molars, identify isolated teeth, and improve the diagnosis of this iconic genus.





## A MORPHOMETRIC REVIEW OF THE FLAMINGO TAPHOGLYPH FROM PUEBLA, MEXICO

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### Keywords

Taphoglyph, Phoenicopteridae, Cenozoic, Mexico, Flamingo

Flamingos (Phoenicopteriformes) are a group scarcely represented in the fossil record of America birds. Their temporal distribution spans from the late Miocene and their geographic records are located in the United States, Mexico, Costa Rica, Argentina, Uruguay and Venezuela. In Mexico, there are fossil records of phoenicopterids dating from the late Cenozoic, located in the states of Mexico, Jalisco and Puebla; with greater distribution in the central zone of the Trans-Mexican Volcanic Belt, suggesting the presence of saline and alkaline lacustrine paleoenvironments with warm temperatures and high precipitation. Located in the municipality of Tepexi de Rodríguez, Puebla State, Mexico, the Pie de Vaca site, a geological formation of the Blancan stage, presents a great diversity of ichnofossils and a flamingo taphoglyph considered one of the most complete specimens in America. A study based on linear osteometry proposed its identification as an extinct species, *Phoenicopterus stocki*. In the present work, 2D geometric morphometry of the skull of the taphoglyph and linear morphometry of the impression of its long bones were performed, comparing it with the three living flamingo genera in America and with the known data of the fossil specimens *Ph. copei*, *Ph. minor* and *Ph. minutus*. Based on these elements, it is possible to discuss both possible taphonomic influences, as well as the taphoglyph differences in size and shape with extant and fossil flamingo genera to more reliably determine its taxonomic status.





## CERVIDAE DIVERSITY DURING THE MIDDLE-LATE PLEISTOCENE OF THE MANZANARES VALLEY (MADRID, SPAIN)

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### Keywords

Artiodactyla, palaeodiversity, evolution, Madrid basin, Quaternary

The river terraces of the Manzanares valley (Madrid, Spain) have a large number of different palaeontological-archaeological sites along its extension. These contain interesting Quaternary records, being especially remarkable those of the Middle-Late Pleistocene for their faunal content. Fossils of the family Cervidae stand out as they have a great diversity of species, such as *Cervus elaphus*, *Capreolus capreolus* or *Megaloceros giganteus*. However, what makes this region more relevant are: the rare *Haploidoceros mediterraneus*, the giant deer *Megaloceros matritensis* and a new species of fallow deer, *Dama celiae*, which are not yet known from elsewhere. The latter species were recovered from sand pits in a terrace of the Manzanares river that dates to the middle Middle Pleistocene (probably MIS9-10, 300-400 ka). Here we show a surprising palaeodiversity of Cervidae species in the Manzanares valley, and present fossils of *Dama celiae* from the Pedro Jaro I and Orcasitas quarries, which consists of various antlers, characterized by a main beam with no posterior ramifications, suggesting a possible relation with the *Dama vallonetensis-Dama roberti* lineage and extending this lineage till very late in the Middle Pleistocene. The appearance of so many rare or unknown species in the Manzanares valley, raises the question of whether this is an endemism related to the particular environment of the Madrid basin.





## NEW MATERIAL OF *PARABRACHYODUS HYOPOTAMOIDES* FROM SAMANE NALA, BUGTI HILLS (PAKISTAN) AND THE ORIGIN OF MERYCOPOTAMINI (MAMMALIA: HIPPOPOTAMOIDEA)

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### Keywords

Anthracotheres, Cladistics, Dental Morphology, Early Miocene, Polymorphism

Revision of the anthracothere *Parabrachyodus hyopotamoides*, endemic to the Lower Miocene of the Indian subcontinent and thus far confused with *Brachyodus*, is made possible by the description of unpublished specimens from the Samane Nala fossil-bearing deposits of the Bugti Hills (Pakistan). This is the first biochronologically constrained occurrence for a comprehensive series of this species. The analysis of cranial and dental morphological variations based on all known specimens of *Parabrachyodus* allows us to provide diagnostic characters for this monotypic genus. These include a four-crested upper molar protocone unique among artiodactyls and several convergences with subfamily Anthracotheriinae, like the two puzzling distal cristae on the last upper premolar protocone. A phylogenetic analysis at the hippopotamoid level, including *Parabrachyodus* and the enigmatic genera *Telmatodon* and *Gonotelma* (both also endemic to the Bugti Hills), is performed for the first time. These phylogenetically related taxa turn out to be basal to the tribe Merycopotamini, leading us to propose a more inclusive definition of the diagnosis of this tribe. Our results formally establish *Elomeryx* as the sister-group of Merycopotamini in Bothriodontinae, and definitely locate the early evolutionary history of Merycopotamini on the Indian subcontinent.





## PLIOCENE JUVENILE OTHOLITES FROM GUERRERO, MEXICO

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### Keywords

Otolithes, sagittal, juvenile fishes, Pliocene, Mexico

The Pliocene fossil materials come from Punta Maldonado that is located near the boundaries of the states of Oaxaca and Guerrero States in Mexico, 206 km southeast of Acapulco and 52 km northwest of Pinotepa Nacional. A sample of 1,274 grams of sandy shale was collected at the top of the outcrops of El Faro at Punta Maldonado Formation. The sample is mainly composed of quartz, biotite, fragments of consolidated calcareous sandstone and micas. The sample was washed with tap water, sieved and sorted under a microscope to recover the microfossils. Microfossil assemblage is composed by foraminifera, ostracods, bryozoans, mollusks, and ichthyolithes. Among the ichthyolithes, the most remarkable are the otoliths. A total of 442 specimens were recovered, all of them belonging to the sagitta type. From these 38 morphotypes were recognized, and 19 were taxonomically identified. The 19 morphotypes identified are associated with juvenile specimens, because the growth rings presented in their structures are faint and poorly developed. The presences of two genera (*Glyptocephalus* and *Ctenosciaena*) show evidence of a wider distribution of these taxa during the Pliocene, embracing from the northeastern to the southeastern of the Pacific Ocean. The abundance of otoliths of juvenile fishes can be explained by associating this fact with a mass mortality generated by harmful algal blooms or the fact that the remains came as part of the excreta of planktivore organisms such as whales.





## ANALYSIS OF SHELL ANOMALIES OF THE TURTLE *ALLAEOCHELYS* (CARETTOCHELYIDAE) FROM THE EOCENE OF ZAMORA (SPAIN)

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### Keywords

Testudines, Cryptodira, Lutetian, Duero Basin, paleopathology

The Paleogene sedimentary successions of the Duero Basin (Castile and Leon Autonomous Community) provided a relatively large diversity of Eocene vertebrates. Testudines are one of the best-represented groups among the extinct vertebrates of the Duero Basin, with several lineages of terrestrial (Testudinidae) and especially aquatic turtles (Podocnemididae, Trionychidae and Carettochelyidae) having been recognized. Contrasting to the other lineages of aquatic turtles of the Duero Basin, the fossil remains of Carettochelyidae are restricted to a single taxon (*i.e.*, *Allaechelys casasecai*), a stage (the Lutetian) and a province (*i.e.*, the Zamora Province). However, the fossil material of Carettochelyidae from that region corresponds to the most abundant and best-preserved record of the lineage in the Iberian Peninsula, several hundred of fossils having been found. A large number of specimens with anomalies of the species have been recognized as a result of the first-hand analysis of the shell remains. Among them, more than 90 specimens have been evaluated in detail through macroscopic examination. A discussion has been established through a differential diagnosis procedure. As a result, different categories of causal agents (such as parasites, trauma or fungi and bacteria) have been identified as potential producers of these *Allaechelys casasecai* anomalies. The interpretation of these anomalous shell remains affords a more global vision of some of the agents that turtles were subjected to in that Iberian Peninsula, as well as their paleoecology and interspecific interactions.





## AN OLIGOCENE HIGH INSECT ICHNODIVERSITY LOCALITY IN SOUTHERN MEXICO

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### Keywords

Oaxaca, Chilapa Formation, *Celliforma* Ichnofacies, semi-arid environments

Trace fossils produced by insects are rarely registered in the Mexican fossil record. The early Oligocene Chilapa Formation crops out in the northwest part of Oaxaca, southern Mexico. The formation represents the marginal facies of a fluviolacustrine sequence in the vicinity of the Santiago Yolomécatl town. In this area, fossiliferous levels harbor trace fossils produced mainly by Hymenoptera and Coleoptera. They are preserved as internal casts. The majority appears in situ, excepting some small specimens that were detached from the rock matrix. Trace fossils are abundant in the upper unit of the stratigraphic sequence. The bottom part of the sequence has an abundance of bee medium-sized chambered systems; meanwhile the medium part has more specimens produced by Coleoptera and rodents. In the top of the sequence, bee small-sized chambered systems are associated with trace fossils of Coleoptera. The assemblage is composed by 14 ichnotaxa: three ichnospecies of *Celliforma*, two of *Rosellichnus*, five undescribed ichnotaxa of Celliformidae, *Teisseirei barattinia*, *Fictovichnus gobiensis*, *F. sciuttoi* and *Pallichnus dakotensis*. There are abundant fragments of tunnels, and isolated cells ranging from a few millimeters to four centimeters in height. A diversity of structures still under study may be of insect or root origin. In some stratigraphic levels, the trace fossils are associated with *Gregorymys* burrow systems, and with horizontal rhizoliths. This assemblage represents the *Celliforma* Ichnofacies. Chilapa ichnoassemblage is notable by their richness and uniqueness in North America. It is comparable with other similar localities worldwide like the early Eocene Asencio Formation in Uruguay.





## OLIGOCENE PALEOSOLS AND ASSOCIATED FOSSILS OF THE CHILAPA FORMATION, OAXACA, SOUTHERN MEXICO

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### Keywords

Santiago Yolomécatl, Alluvial Geomorphic Dynamics, Environmental Conditions Reconstruction, Erosion-Deposition Events

Fluvio-lacustrine sediments interbedded with paleosols and volcanoclastic deposits constitute the Oligocene Chilapa Formation, in southern Mexico. A ten-meters section was analysed to characterise the paleosols and the trace fossil associations. A total of 12 paleosol levels were analysed. From the bottom to the top, the paleosol sequence is interpreted in three episodes: a) Paleosols with A horizons, developed on alluvial sediments, with cross-bedding stratification and imbrication. Their deposit was on periods of floodplain aggradation, because of climatic humid conditions, with short intervals of soils development. *Fictovichnus gobiensis* and Celliformidae specimens were recorded; b) Well-developed paleosols with Btk, Btok, and Brk horizons, with abundant and vertical rhizoliths. The paleosols are characterised by their clay illuviation, vertic properties and oxide-reduction processes. Their matrix has an important carbonate's enrichment. The pedogenetic processes could indicate humid climatic conditions, changing into arid conditions. c) An upper alluvial strata, weakly developed paleosols with A/C horizons, an alternation with moderately developed paleosols with Btok horizons, which reflects dry and humid conditions. During humid periods, the sediments were transported and deposited to a delta river, with interruptions of the pedogenetic processes. The Btok horizons show two climatic signals: humid conditions that favour the clay transport, and dry conditions evidenced by carbonate accumulation on the matrix. In this part of the deposit, *Fictovichnus* spp. and Celliformidae specimens, and burrows produced by *Gregorymys* spp. are recorded. The changes in the deposit could be related to the climate change and the volcanism recorded in the area during the Oligocene.





## QUATERNARY GASTROPODS AND BIVALVES FOSSILS IN KARSTIC CAVES OF SOUTHERN BRAZIL

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### Keywords

Speleology, Mollusks, Konzentrat-Lagerstätte, Geoconservation

Paleontological assemblages found in Brazilian karstic caves are not unusual, although being characterized specially by Pleistocene megafauna. In the case of Southern Brazil, there are no known published examples of invertebrate fossils found in carbonatic cave systems. Therefore, we hereby bring the first report on the presence of mollusk fossils preserved by speleological processes in a quaternary karstic cave in the state of Santa Catarina, Southern Brazil. The studied site is located inside a quarry of Neoproterozoic marble and metamarls of the Rio da Areia Formation of the Brusque Metamorphic Complex. Although the cave was found almost destroyed, hundreds of fragments and whole specimens of terrestrial pulmonated gastropods and bivalves were found associated with speleothem structures. The size of the mollusk's valves varied from 1 to 15 cm, with a high predominance of gastropods of the genus *Megalobulimus*, while the yet taxonomically unidentified bivalves range from 1 to 4 cm, all preserved by incrustation of calcite. Most fossils were already removed from their original positions, but a considerable amount was still incrustated in the cave's walls. About 150 kg of speleothems and fossils were collected and cataloged in the scientific collection of the Laboratório de Paleontologia of Universidade Federal do Paraná with labels ranging from UFPR 0978 PI to UFPR 0992 PI. X-ray Computed Tomography showed speleothem involving the mollusk valves in various speleological precipitation stages. Stable isotope analyzes and C<sup>14</sup> dating of the described valves should still be evaluated for better understanding the fossil assemblage's age and paleoenvironmental conditions.





## BENTHIC FORAMINIFERA AS BIOSTRATIGRAPHICAL AND PALEOECOLOGICAL INDICATORS: AN EXAMPLE FROM THE MIOCENE DEPOSITS IN GEBEL ABU SHAAR EL QIBLI, GULF OF SUEZ REGION, EGYPT

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### Keywords

Early Miocene, Gharamul Formation, Gebel Abu Shaar El Qibli, Gulf of Suez, Egypt

The foraminiferal contents of the Miocene deposits exposed in two sections in Wadi Bali and Wadi Kharaza, Gebel Abu Shaar El Qibli plateau, Western side of the Gulf of Suez, Egypt, were carefully studied for their large benthonic and planktonic foraminiferal content. Based on their lithofacies variations and microfaunal content, two rock units were studied from base to top: the Abu Gerfan Formation, consisting of polymictic conglomerates (Early Miocene, Aquitanian), and the overlying Gharamul Formation composed by carbonate and mixed siliciclastic-carbonate (Middle Miocene, Burdigalian to Langhian). Detailed larger and planktonic foraminiferal investigations led to the recognition of three foraminiferal zones from base to top: 1) *Miogypsinoides complanatus* / *Porosononion granosum* Zone (SBZ 24), comprising the Abu Gerfan Formation (Early Miocene Aquitanian), 2) *Miogypsina globulina* Zone (SBZ 25) representing the lower unit of the Gharamul Formation, and correlated with the Early Miocene (Burdigalian) and lastly 3) *Borelis melo melo* Zone (SBZ 26), comprising the upper part of the Gharamul Formation (Middle Miocene, Langhian). The variation in lithology and foraminiferal assemblages indicates an overall shallowing upward trend, from a continental, subaqueous fan delta facies in the Abu Gerfan Formation to an inner platform reefal facies represented in the topmost part of the Gharamul Formation.





## A NEW LEAF OF LEGUMINOSAE IN THE MEXICAN AMBER

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### Keywords

Amber, Fossil Leaves, Leguminosae, Miocene

One of the most important amber deposits with bioinclusions is the one from Chiapas state in southern Mexico. This amber is outstanding because it has an age ca. 13-25 Ma. (Early Miocene) and is now in the Neotropical region. Most paleontological reports in the area are about animals, and few records correspond to plants. Angiosperms (flowering plants) are the most frequently recorded group within this amber, with ca. 18 families based principally on fossil flowers. Leguminosae is the third most diverse family among extant angiosperms, has a worldwide distribution, and is particularly diverse in the Neotropics region, although it has a relatively poorly documented fossil record. In this study, we presented bifoliolate-compound leaves preserved in amber. One pair of leaflets are marginally attached to the short petiolules. Each leaflet is ovate to oblong with an entire margin, asymmetrical base and acuminate apex, pinnate primary vein, brochidodromous secondary veins, mixed percurrent tertiaries, and reticulate irregular quaternary. Abundant round glands are distributed on the surface of the leaflets. These characteristics are comparable with the compound leaves of extant members of Leguminosae, such as genera *Hymenaea*, *Cynometra*, *Peltogyne*, *Guibourtia* (Caesalpinioidea, Detarieae) and *Pithecellobium* (Mimosioidea, Ingae). This new fossil reported in the region supports the presence of rainforest neotropical lineages at low latitudes in North America.





## FIRST POTENTIAL RECORD OF “TERROR BIRD” FROM THE PALEOGENE OF NORTH AMERICA (AVES: CARIAMIFORMES: PHORUSRHACIDAE)

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### Keywords

Terror bird, Phorusrhacidae, North America, early Eocene, biogeography

“Terror birds” were apex predators throughout most of the Cenozoic of South America. I report a flightless predatory bird from the Ypresian (Wa-2 NALMA), Early Eocene, Willwood Formation, Clarks Fork Basin, north central Wyoming, USA. It is comprised of a raptorial premaxilla, complete wing, quadrate, and pedal phalanges. The entire bird skeleton collection of the Smithsonian Institution was examined for first-order comparison. The fossil is recovered within Phorusrhacidae in a preliminary cladistic analysis (wing characters of Degrange *et al.*, 2015), although no single character uniquely diagnoses Phorusrhacidae. It most closely resembles psilopterine phorusrhacids, but differs from them in some details, *e.g.*, non-pneumatic humerus. If correctly identified, then it is the only record of Phorusrhacidae from North America preceding the Great American Biotic Interchange. Like many or most phorusrhacids, the fossil bird appears to have been flightless. It groups outside of the range of volant birds in a ternary plot of intramembral bone lengths, and it shares morphological characters known otherwise only in flightless birds. Wing characters associated with flightlessness in unrelated birds raise the possibility of convergence, hence phylogenetic inference. Pronounced muscle insertions and impressions for the attachment of remiges on the ulna suggest other potential uses of the wings, such as intraspecific combat and agonistic display as in some other flightless birds. If indeed a flightless phorusrhacid, then the biogeography of the fossil is provocative because phylogenomic timetree analyses date the origin of Cariamiformes to the late Paleocene when North and South America were ostensibly isolated from one another.





## DENTAL ERUPTION AND ADULT DENTITION OF THE ENIGMATIC PTOLEMAIID *QARUNAVUS MEYERI* FROM THE OLIGOCENE FAYUM DEPRESSION (EGYPT) REVEALED BY MICRO-COMPUTED TOMOGRAPHY CLARIFIES ITS PHYLOGENETIC POSITION

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### Keywords

Afrotheria, Fayum, Mammalia,  $\mu$ CT scan, Paleogene

The Paleogene is a very important time period for mammalian evolution because it documents the first occurrence of many groups. One such group is the enigmatic *Ptolemaiida*, almost exclusively known from the early Oligocene of the Fayum Depression in Egypt, where it is represented by five species belonging to three genera, *Ptolemaia*, *Qarunavus* and *Cleopatrodon*. Among these, *Qarunavus meyeri* is especially rare, as it is only known from two partial mandibles, both of which belong to juvenile individuals. Herein, the affinities of this taxon are re-investigated applying micro-computed tomography ( $\mu$ CT), thus, enabling the study and comparison of its unerupted permanent dentition with that of adult mandibles of the other ptolemaiidans. The new data confirm that *Qarunavus meyeri* is a valid species, distinct from all other ptolemaiidans. Both the morphological comparison and a phylogenetic analysis suggest a closer relationship of *Qarunavus* to the genus *Cleopatrodon* than to *Ptolemaia* and places *Qarunavus* in the family Ptolemaiidae. Furthermore, the  $\mu$ CT analysis confirmed that *Qarunavus* exhibits a single very small lower incisor next to a rather large canine, an unusual combination not known from any modern mammal. Lastly, the assessment of the eruption sequence of the permanent dentition in *Qarunavus meyeri* implies a delayed dental eruption of the permanent teeth for the species, with only m1 and m2 being erupted, while the mandible seems to have reached almost its potential adult size, when compared with adult mandibles of the other ptolemaiids. This may provide further support for the hypothesis of *Ptolemaiida* belonging to Afrotheria.





## THE CARNIVORAN GUILD FROM THE LATE MIOCENE HOMINID LOCALITY OF HAMMERSCHMIEDE (BAVARIA, GERMANY)

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### Keywords

Carnivora, ecology, Miocene, Neogene, Europe

The Late Miocene locality of Hammerschmiede (Germany) has yielded an astonishing diversity of vertebrates, including 84 mammalian species and 28 different carnivorans among the four fossiliferous layers. In particular, the main layers HAM 4 (11.44 Ma) and HAM 5 (11.62 Ma) have been found to host 21 and 15 species, respectively. Rarefaction analysis showed that such numbers exceed those of known stratified localities and are comparable only to the fissure fillings of La-Grive-Saint-Alban (France). The First and Last Occurrence Dates of several genera and species are reported in the locality. The profile of the locality concerning the Number of Species and the Number of Individuals per family is unique among the Miocene localities of Europe and presents several highlights such as the presence of the rare *Potamotherium*, the abundance of viverrids and the rarity of felids and amphicyonids. The discovered carnivorans were attributed to palaeoecological categories based on their body mass, locomotion, and diet. Ecomorphological comparison based on these attributes showed that most species were able to reduce competition by occupying different ecological niches, but some cases of ecological overlap were also found. This is an indication that the rich ecosystem of Hammerschmiede offered diverse resources that allowed the subsistence of a plethora of carnivorans, including taxa that occupied broadly similar ecological niches. Finally, the two main layers exhibit some differences in their carnivoran components with HAM 4 (larger river) dominated by small-/medium-sized piscivores and generalist carnivores, whereas HAM 5 (smaller rivulet) also includes large-sized durophagous and hypercarnivorous forms.





## A NEW SPECIES OF THE GENUS *LEBIA*: THE FOURTH RECORD OF THE TRIBE LEBIINI (COLEOPTERA, CARABIDAE) IN ROVNO AMBER AND ITS IMPORTANCE

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### Keywords

*Lebia*, ground beetle, new record, fossil, Priabonian

A new species of colorful foliage ground beetle (Coleoptera: Carabidae) is reported in the late Eocene Rovno amber (Ukraine). It is the first record of the genus *Lebia* and the fourth fossil species of the tribe Lebiini described in Rovno amber. This fossil beetle is deposited in the amber collection of the Schmalhausen Institute of Zoology of the National Academy of Sciences of Ukraine, Kiev (SIZK). In addition, two fossil *Dromiusina* species have recently been described and one *Cymindina* species have been reported from Rovno amber. Fossil Lebiines are not uncommon in collections. However, only five extinct species of the genus *Lebia* are known: *L. protospiloptera* from Florissant (latest Eocene of the USA), *L. harreli* from the Sunchal formation (Paleocene of Argentina), *L. amissa* from Salzhausen (Miocene of Germany), *L. minuscula* from Lake Chambon (Gelasian of France), and one undescribed species from late Eocene Baltic amber. *Lebia* is a cosmopolitan genus comprising 740 extant species in 18 subgenera. This genus has more than 90 species in the Palaearctic fauna. The adults are predators, but all known larvae are ectoparasitoids of pupae or prepupae of leaf beetles (Chrysomelidae). The presence of *Lebia* could be a proxy for the unknown chrysomelid diversity in the Eocene amber forests. Cenozoic leaf beetles are not connected with conifers so it was a considerable taphonomic bias against the capture and preservation of bigger representatives of Chrysomelidae in the succinites; the commonest chrysomelids in amber are small flea beetles. Still the presence of other chrysomelids in mixed amber forests is very probable, because leaf beetles are common in Europe at least since earliest Eocene (Fur Formation, Denmark) or even early Paleocene.





## LATE PLIOCENE FORAMINIFERA FROM THE CHOTT BEGHEDAD AREA (NORTHERN ORIENTAL SAHARA, ALGERIA) AND THEIR PALEOENVIRONMENTAL IMPLICATIONS

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### Keywords

Late Pliocene, foraminifera, Chott Beghedad, Algeria, paleoenvironment

The Algerian north oriental Sahara Cenozoic deposits contain an abundant microfossil, used as a key tool to interpret the paleoenvironment. The present study focused on the Late Pliocene lacustrine deposits from the section of the Chott Beghedad. The succession consists of sand and clayey-gypsum alternation, and it offers an opportunity to investigate the benthic foraminifera of the Algerian north oriental Sahara. The 14 collected clay and sand samples have brought benthic foraminifera (26 species and 22 genera) and planktic foraminifera (09 species and 04 genera). The palaeoecological index of the Late Pliocene benthic tests of foraminifera indicates shallow environment, oxygenated, and mesotrophic environments in the lower part of the section. However, stress conditions are documented in the upper part of the section, with poor oxygenation and high trophic levels, causing a low diversity of foraminifera. These preliminary results about the paleoecology of the studies foraminifera of the Algerian north oriental Sahara should be compared to other proxies with the neighboring regions, in order to determine its geographical and time extent.





## MIOCENE TROPICAL STORMS: CARBONATE FRAMEWORK APPROACHES AND GEOCHEMISTRY PROXIES IN A RESERVOIR MODEL

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### Keywords

Brazilian equatorial platform, Pirabas Formation, heterozoan reef, climate changes, tempestites

The Bragantina Platform is an onshore sedimentary succession of the Brazilian equatorial margin that occurs in northwestern Brazil, typically on the equatorial western Atlantic coast. Most of the latest Neogene succession of this carbonate-siliciclastic platform consists of the late early to late middle Miocene Pirabas Formation, which is subdivided into pre-Amazonian and pre-Panamanian Isthmus stages (*i.e.*, prior to the establishment of the transcontinental drainage of the Amazon River and the closure of the interoceanic seaway between the Atlantic and Pacific oceans). High-energy coastal storms and hurricanes as consequences of trade wind anomalies during the Neogene affected shallow-water inner marine heterozoan reef deposits of the Pirabas Formation. A chaotic overlap of benthic infauna and epifauna, and demersal and pelagic species in the same section was analyzed using petrography, petrophysics, micro- and macropaleontology, taphonomy, and geochemistry to understand sedimentary and paleoenvironmental processes. The high-energy wave environment caused severe damage to the shallow-water reef, and the resulting chaotic reef architecture, together with carbonate diagenesis, was favorable for the porosity and permeability of the oil and gas reservoirs in the area. The Pirabas Formation and relict faunal assemblages together with climatic anomalies derived from tropical storms and the sedimentary dynamics, are the best record of tempestites from the Neogene marine tropical American environment to elucidate the evidence that high sea multiple wave energy affects the inner shallow-water Brazilian equatorial platform.





## RE-EVALUATION OF THE CROCODYLIAN REMAINS FROM THE LUTETIAN LOCALITY OF TURÓ DEL CASTELL, BANYOLES MARL FORMATION, NE IBERIAN PENINSULA

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### Keywords

Taxonomy, Eocene, Ebro Basin, Tomistominae

During the Eocene, the Iberian Peninsula was inhabited by a significant diversity of crocodyliformes — such as the sebecosuchian *Iberosuchus*, the crocodyloids *Asiatosuchus* and *Duerosuchus*, and the alligatoroid *Diplocynodon* — being especially well represented in the Duero Basin, and the western and central part of the Ebro Basin. However, very little evidence is reported from the eastern part of the Ebro Basin. In the 1960's, crocodylian skeletal remains were discovered at the Middle Lutetian (Middle Eocene) locality of Turó del Castell (Banyoles Marl Formation, NE Iberian Peninsula). 40 years later this specimen was tentatively identified as a tomistomine crocodylian, although such attribution was based on the interpretation of the local environment rather than morphological characters. Here, we present a re-evaluation of those crocodylian remains (13 elements), and several additional ones, consisting of tooth bearing bones elements, dorsal osteoderms, and postcranial bones. The presence of diagnostic features on both teeth (large, long, and slightly conical) and osteoderms (with large subcircular pits surrounding the dorsal keel, and smaller ones located in the most external parts of the element) suggest a tentative referral of the material to the subfamily Tomistominae. Therefore, this study represents one of the first, and the most updated definitive report of tomistomine crocodylians in the eastern Ebro Basin (Iberian Peninsula), where mainly the genus *Diplocynodon* had been reported. Furthermore, the co-occurrence of several hyaline foraminifera taxa corroborates a lagoonal depositional environment for el Turó del Castell locality, which coincides with one of the habitat preferences of extinct tomistomine crocodylians.





## FOSSILDIAGENESIS OF *LESTODON ARMATUS* REMAINS FROM PLEISTOCENE PLAYA DEL BARCO SITE (BUENOS AIRES PROVINCE, ARGENTINA)

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### Keywords

Taphonomy, Mineralogy, Histological Preservation, Geochemistry, South America

Fossil diagenetic approach including mineralogical, geochemical, and paleohistological features present in the fossils of the extinct megamammal *Lestodon armatus* (Xenarthra, Mylodontidae) have been performed. Thin section of 15 ribs and vertebrae fragments were recovered from Late Pleistocene fluvial deposits at Playa del Barco (southwestern Buenos Aires Province, Argentina). They were examined under light microscope, polarizing petrographic microscope, and scanning electron microscope (SEM), combining with chemical analysis using energy dispersive spectroscopy (EDS) and micro-X-ray diffraction ( $\mu$ XRD). Original bone histology is well preserved without microbial attack signs, although numerous radial microcracks were identified in the secondary osteons of all specimens evidencing wet depositional environment. Presence of hydroxyapatite, as the main mineral component of the bone matrix, suggests that there were no significant compositional changes in the internal crystalline structure. The chemical composition of infilling and crusts indicates that the enrichment with new elements was due to direct exchange with the host deposits. Mineral precipitation infilling fissures, cracks, and cavities of the bone microstructure (*i.e.*, osteocyte lacunae, canaliculi, vascular canals, trabecular structure) allows us to identify different diagenetic pathways. Some samples were buried in a continental vadose zone (fillings of iron oxides, micrite with quartz grains and dogtooth calcite cements) while other were buried in freshwater phreatic zone (blocky mosaic calcite). The interpretation of the microstructural and mineralogical analysis is consistent with the environmental context of the Playa del Barco and can be used to reconstruct the post-burial history of the specimens.





## FIRST DATA ON THE SQUAMATE REPTILES FROM CREVILLENTE 2 (MN11, LATE MIOCENE; SPAIN)

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### Keywords

Reptilia, Turolian, Iberian Peninsula, Palaeoecology, Palaeoclimatology

Many vertebrate sites are known in the continental Neogene of the area of Crevillente (Alicante, Spain) from a stratigraphic interval that covers the entire Turolian (Late Miocene). Some of these localities have yielded rich micromammal assemblages, but only three of them, Crevillente 2, 15 and 16, contain macromammal remains and only the first one can be considered as a rich macrovertebrate site. Thus, Crevillente 2 is one of the few sites with an abundant fauna of both micro- and macromammal species of this chronology. Therefore, this site was designated as the reference locality for zone MN11 (early Turolian, Late Miocene). Although the remains of mammals from Crevillente 2 have been the subject of numerous studies, this has not been the case with the herpetofauna. So far only the chelonians has been studied, determining the presence of three taxa: *Paleotestudo catalaunica*, *Titanochelon bolivari*, and *Cheirogaster* sp. In the present work, we study isolated remains of squamate reptiles from the excavations carried out from 1985 to 1988. The faunal list is composed by one scincid (Scincidae indet.), two lacertids (cf. *Lacerta* sp. and Lacertidae indet.), two anguids (cf. *Pseudopus* and cf. *Ophisaurus s.l.* sp.), and three snakes (Colubridae indet., Natricinae indet., and Viperidae indet. —Oriental Vipers group—). Based on the fossil assemblage, the surrounding area would be dominated by open areas with sparse tree and shrub formations. Finally, the palaeoclimate in the area may have been characterized by warmer and moister conditions compared to the current climate.





## HERPETOFAUNA FROM THE EARLY MIOCENE (MN 4) OF ARAIA D'ALCORA OUTCROP (RIBESALBES-ALCORA BASIN, EASTERN SPAIN)

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### Keywords

Amphibia, Reptilia, Biostratigraphy, Aragonian, Iberian Peninsula

The Early Miocene is a crucial moment in the constitution of the modern faunas of reptiles and amphibians, especially regarding snakes. However, there are very few studies focused on herpetofauna in Iberian sites of this chronology. In the present work, we studied the palaeoherpetofauna from 45 sites of the Ribesalbes-Alcòra basin. All of these remains were recovered from the Campisano ravine of the Araia/Mas de Antolino outcrop, near the village of Araia d'Alcòra (Castelló, Spain). The deposits of this ravine are divided in the sections of Mas dels Coixos, Mas de Torner, Araia Cantera Sud, Barranc de Campisano, Foieta la Sarra, Mas d'Antolino B, and Corral de Brisca. According to the recovered small mammal assemblages from these sites, they all belong to Early Aragonian age (MN4, Early Miocene). The taxa identified include one urodele (*Lissotriton* sp.), two anurans (Bufonidae indet. and non-bufonid Anura indet.), one crocodile (Crocodylia indet.), one tortoise (Testudinidae indet.), one amphisbaenian (*Blanus* sp.), one chameleon (Chamaeleonidae indet.), one gecko (Gekkota indet.), two lizards (Lacertidae indet. 1, and Lacertidae indet. 2), and four snakes (Scolophoridae indet., ?Booidae indet., *Palaeonatrix* sp., and Viperidae indet.). This assemblage is similar to other ones described in the early Miocene sites from Western Europe, thus it points out the homogeneous composition of the palaeoherpetofauna during this epoch in this region. The fossil record of Chamaeleonidae is really poor globally, the finding of an indeterminate form of this clade in the studied sites confirms the presence of these squamates in the Iberian Peninsula during the Early Miocene.





## THE FIRST RECONSTRUCTION OF THE ENDOCRANIUM OF THE EUROPEAN EOCENE PODOCNEMIDID TURTLE *NEOCHELYS ARENARUM*

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### Keywords

Pleurodira, Podocnemididae, France, CT scan, 3D reconstruction

Podocnemididae is one of the three lineages of Pleurodira that are part of the current biodiversity. All extant pleurodiran turtles are distributed in warm areas of the southern hemisphere continents. However, several representatives are identified in the fossil record of the northern continents, at Mesozoic and Cenozoic epochs with warm global temperatures. In this sense, *Neochelys* was a diverse podocnemidid in Europe, identified from the early to the late Eocene. It is represented by several species, one of the best known being the French Ypresian (early Eocene) *Neochelys arenarum*. It is not only identified by shells but also by the skull. The neuroanatomical information on the crown Pleurodira has been remarkably increased during the last years, including the analysis of several extant but also scarce extinct taxa. The three-dimensional reconstruction of the neuroanatomical elements of two skulls of *Neochelys arenarum* is presented here. It represents the first complete neuroanatomical analysis based on an extinct member of Podocnemididae so far performed. The comparison of the internal cranial cavities and canals of this taxon (specially the endocranial and labyrinthic cavities and the circulatory and nervous canals, with those of other extant and extinct pleurodires, particularly podocnemidids, allow us to carry out its detailed neuroanatomical characterization.





## A NEW CRYPTODIRE FROM THE EOCENE OF THE NA DUONG BASIN (NORTHERN VIETNAM) SHEDS NEW LIGHT ON PAN-TRIONYCHIDAE FROM SOUTH EAST ASIA

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### Keywords

Eocene, Turtle, Pan-Trionychinae, Nilssonina, Asia

Pan-Trionychidae (softshell turtles) represents one of the most diverse aquatic radiations among cryptodiran turtles with more than a hundred fossil and extant species and a fossil record dating back to the late Early Cretaceous. The group is characterized by having a reduced carapace lacking peripherals and pygals. Here we report a new species representing a pan-trionychid from the middle–upper Eocene (late Bartonian–Priabonian, 39–35 Ma) of the Na Duong Basin in northern Vietnam. It represents one of the best documented and most completely known Palaeogene pan-trionychid species from Asia. The new species can be diagnosed by (1) its relatively small size, (2) the absence of a preneural, (3) the presence of well-developed straight ridges on the costals and neurals in adults, (4) stronger ridges posteriorly and (5) entoplastron callosity in shape of a bulge. The phylogenetic analysis recovers the new species within Pan-Trionychinae in an unresolved polytomy within the genus *Nilssonina*. A comparison with plastomenids, pan-trionychids from the Palaeogene and extant trionychids from Asia also finds the most similarities between the new taxon and species from extant *Nilssonina*. A particular close resemblance exists between the new species from the Na Duong Basin of northern Vietnam and '*Trionyx impressus*' (a pan-trionychid from the Maoming Basin of Southern China). A close relationship between both species further supports the hypothesis that a close connection between those localities exists, as already exemplified by other faunal elements such as pan-geoemydids and crocodylians.





## A REVISION OF THE EARLY OLIGOCENE ALLIGATOROID *DIPLOCYNODON MUELLERI* FROM EL TALLADELL (EBRO BASIN, IBERIAN PENINSULA)

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### Keywords

Diplocynodontidae, cranial anatomy, basal alligatoroid, Lagerstätten site.

El Talladell (Tàrrega, Lleida) is a well-known fossil Lagerstätten from the early Oligocene of the Ebro Basin, Iberian Peninsula. This site is not only notable for the abundance of specimens in anatomic connection but also for being the type locality of the alligatoroid *Diplocynodon muelleri*. *Diplocynodon muelleri* was named in the first half of the 20th century as *Hispanochampsia muelleri*, but it was not until two decades ago that a revision of the type specimen confirmed the synonymy between both genera. According to sedimentological data, *D. muelleri* preferably inhabited lacustrine environments, and has been found only in the Iberian Peninsula. Due to the global cooling that took place during the Eocene-Oligocene boundary, there was a global decline in the crocodylomorph diversity, being *Diplocynodon* the only crocodylian lineage that persisted in Europe. In the Iberian Peninsula, two species of *Diplocynodon* have been described: *D. tormis* (middle Eocene, Duero Basin) and *D. muelleri*. Recent studies questioned differences between *D. muelleri* and *D. tormis*, considering *D. tormis* a junior synonym of the former. Some authors also pointed out that several of the features frequently used to identify *D. muelleri* and *D. tormis* are subject to intraspecific and ontogenetic variability, which may affect results. In order to address this issue, in this study, a review of both published (the type specimen, skulls, and postcranial) and unpublished (mainly skulls, and postcranial) material was conducted, implying reinterpretation of the species validity. Even more detailed comparisons are required, our preliminary results suggest that both species are valid.





## STATE-OF-THE-ART KNOWLEDGE ON SOUTH-AMERICAN FOSSIL PROBOSCIDEANS AND FUTURE PERSPECTIVES

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### Keywords

Quaternary, megafauna, Mammalia, Taxonomy, Paleobiology

Two gomphotheres are recognized in the Quaternary of South America: *Cuvieronius hyodon* Fischer 1814 and *Notiomastodon platensis* (Ameghino 1888); since Cuvier, the knowledge of these gomphotheres increased significantly, although many questions are still open. Here, the most updated knowledge is presented, as well as the greatest information gaps on these gomphotheres. *Cuvieronius hyodon* has a Panamerican distribution, with four new records in South America: Villa de Leyva (Colombia, first record in this country), Piura (Peru, two records), and Quito (Ecuador). *Notiomastodon platensis* has an abundant fossil record all over South America, being endemic to this continent, and presents high polymorphism on tusks and last molars, probably related to temporal/regional variations. Both proboscideans had generalistic/opportunistic feeding habits and occurred from lowlands to highlands, and might have used Andean valleys as migratory routes. Also, they interacted with ancient humans during the late Pleistocene/early Holocene, however, the use of *Cuvieronius* remains by Paleoamericans are known from Mexico and absent in South America, while *Notiomastodon* was the subject of hunting/ butchering activities all over this continent. Phylogenetic studies (morphological and molecular using aDNA) pointed out that the origin of these brevirostrine gomphotheres' lineage might have occurred in the middle/late Miocene, possibly in North America. Nevertheless, their diversity and evolutionary history during the late Miocene/Pliocene is still unknown, as well as the drivers for their extinction, accurate temporal/geographical distributions, paleobiological attributes, and biogeography.





## BIZARRE *LEPEICHNUS GIBERTI*: AN ADDITIONAL ICHNOGENETIC STAGE

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### Keywords

Ichnology, Bioturbation, *Lepeichnus giberti*, Miocene, Lepe

*Lepeichnus giberti* Belaústegui *et al.*, 2016 is a complex bioturbation structure described from the upper Miocene shallow-marine deposits of the Guadalquivir Basin (Lepe, Huelva, SW Spain). This ichnotaxon has been interpreted as probably produced by a decapod crustacean as the result of the very likely combination of three different behaviors: dwelling, deposit feeding, and farming. The exceptional material of *L. giberti* allowed to recognize its different 'ichnogenetic stages' and hence to propose the new concept of 'ichnogeny'. To date, ichnogeny has been identified both for bioturbation and bioerosion structures. *Lepeichnus giberti* consists of two vertical shafts (one deeper than the other; with or without bioglyphs on the walls), which are interconnected by a horizontal C-shaped gallery (i.e. parallel to subparallel to bedding); this gallery exhibits a horizontal/subhorizontal, dextral or sinistral hook-shaped branch. The ichnogeny of *L. giberti* could be summarized in the following ichnogenetic stages: 1) the formation of a simple and shallow vertical burrow; 2) the development of a horizontal C-shaped gallery and the second vertical burrow; 3) the thickening of the lining; and 4) the development of the hook-shaped branch. Based on a recently collected specimen at the type locality, an additional, bizarre, and very likely terminal ichnogenetic stage for *L. giberti* is presented herein. This new specimen exhibits a helical branch more complex to that of the typical hook-shaped ones. The development of this new helical pattern could reinforce the agrichnial hypothesis, idea already proposed for other helical ichnogenera such as *Gyrolithes* and *Lapispira*.





## THE FIRST FINDINGS OF THE EQUATORIAL EARLY ANDEAN PLEISTOCENE PALEOCLIMATE FROM DIATOMS RECORD A PALEOLAKE SUCCESSION

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### Keywords

Guayllabamba Basin, San Miguel Formation, diatoms, temperature, thermal stratification

The paleoclimate interpretation of records derived from diatoms in Andean paleolakes during the Pleistocene is scarce. Here we study The San Miguel Formation, a lacustrine sedimentary deposit belonging to the Early Pleistocene period, which is located in the Guayllabamba basin, an Ecuadorian continental basin under the influence of the Intertropical Convergence Zone (ITCZ). Along the San Miguel Formation are very well-varved diatomite deposits. The Absolute Diatom Abundance (ADA%) analysis explores the relationship between the distribution of microfossil diatom species, temperature change, and thermal stratification in the Guayllabamba basin during the Pleistocene. We collected 30 sediment samples from 5 Sections (I-V) spread out along the upper 20 m of the San Miguel Formation. Sections I to IV show a trend with a decrease upward of ADA% of *Aulacoseira ambigua* and *Aulacoseira pusilla* and an increase in ADA% of *Aulacoseira granulata*, *Discostella stelligera*, *Discostella pseudostelligera*, and *Cyclotella discostelliformica*. We interpret this diatom change as a deglaciation period with an increase in the stratification of the water column. Section V displays a sharp change of diatom association with a bloom of *A. ambigua*, *A. pusilla*, *C. placentula*, and *C. meneghiniana*, and a drop-off of *A. granulata*, *D. stelligera*, *D. pseudostelligera*, *C. discostelliformica* which we considered as an abrupt decrease of temperature. However, diatoms *C. placentula*, *C. discostelliformica*, and *C. meneghiniana* have an inverse ADA% relation, likely a strong water column stratification with oligotrophic conditions. Our results suggested that the Ecuadorian Andes were glaciated during Early Pleistocene, and temperature fluctuations that triggered deglaciation events.





## CAUDAL TUBES TAPHONOMY OF THE NEOGENE GENUS *ELEUTHEROCERCUS* (CINGULATA, GLYPTODONTIDAE) AND ITS TAXONOMIC IMPLICATIONS

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### Keywords

Xenartha, alteration, ornamentation, biological entity, taxonomy

*Eleutherocercus* is a glyptodont Doedicurinae genus with records in the Late Miocene-Late Pliocene of southern South America. It includes six species, most of them recognized on the basis of morphological characteristics of the dorsal carapace and caudal tube. One interesting aspect to highlight in this taxon is the notable difference between the ornamentation pattern of the carapace and the caudal tube. Very well-preserved specimens evidence that the osteoderms of the carapace have a smooth surface with numerous large foramina, representing the original pattern. On the contrary, for caudal tubes two ornamentation patterns were described: Type A represented by a “rosette” pattern, which includes a central figure surrounded by several small figures, and Type B represented by a smooth surface pattern with large foramina arranged in a circular disposition. Recent studies on living and fossil cingulates suggested that the original ornamentation pattern can be modified by taphonomic processes. Here, the study of several well-preserved caudal tubes reflects that the “rosette” pattern represents the original ornamentation in *Eleutherocercus*. Likewise, we infer that the Type B ornamentation is the result of taphonomic alterations, which generated the degradation of the figures that compose the original “rosette” pattern and the enlargement of the foramina. Considering that some species of *Eleutherocercus* (e.g., *E. tucumanus* (MACN2893) and *E. paranensis* (MACN6253)) have been defined based on Type B ornamentation pattern, their taxonomic assignment should be reviewed. We finally remark on the importance of taphonomy as a complementary discipline to avoid systematic and phylogenetic misinterpretations.





## INDIAN VEGETATION RESPONSE TO PAST MONSOON CHANGES IN A WARM WORLD: EVIDENCE FROM A POLLEN RECORD OF INTERGLACIAL MIS 11

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### Keywords

Pleistocene interglacials, MIS 11, Indian summer monsoon, Tropical forest, Marine pollen analysis

The Indian Summer Monsoon (ISM) is the dominant Asian monsoon subsystem concerning energy flux, being considered one of the Earth's strongest hydrological regimes. It brings up to 90% of the annual rainfall into the Core Monsoon Zone (CMZ), where the ISM has its most representative expression. Alarming, the uncertainty in ISM precipitation projections is still high due to the complexity of simulating its various interconnections. ISM records of past interglacials, warm periods as the Holocene, are thus critical to understand the main drivers of the ISM natural variability. This study focus, for the first time, on the Indian monsoon-induced vegetation change during MIS 11 (425-374 ka), an important analogue of the Holocene owing to its similar astronomical configurations, higher than present-day sea level and CO<sub>2</sub>-driven climate warming. Pollen analysis at Site U1446, strategically retrieved from the CMZ, shows a first major forest phase during MIS 11c followed by two forest phases separated by open vegetation periods indicating a shift to drier conditions due to reduced ISM. The maximum expansion of the forest occurs during the highest level of incoming solar insolation of MIS 11c, which reveals the dominant influence of this forcing on the ISM rainfall under interglacial conditions, i.e., relatively high sea-level and CO<sub>2</sub>. However, during the second part of MIS 11 (MIS 11b-a, 396-374 ka) we suggest that insolation forcing is buffered by the influence of increasingly larger ice-sheets and lower CO<sub>2</sub>. Our results highlight, therefore, the complex interplay between the forcings in driving ISM-induced vegetation change under the distinct boundary conditions of interglacial MIS 11.





## OSTEOLOGICAL AND MORPHOLOGICAL ANALYSIS OF SPECIMENS ATTRIBUTED TO THE GENUS *PYCNODUS* (AGASSIZ, 1835) FROM PALEOCENE DEPOSITS OF CHIAPAS

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### Keywords

*Pycnodus*, Chiapas, meristic-morphometric analysis, new species, Paleocene

*Pycnodus* is an emblematic fish of the order Pycnodontiformes, a primitive extinct group of Triassic-Eocene actinopterygians that inhabited tropical and subtropical epicontinental seas around the planet. The genus included many nominal species that eventually were synonymized or reclassified. Recently, a meristic and morphometric study showed that all *Pycnodus* specimens from the Eocene of Monte Bolca, Italy, represent only one species, *P. apodus*. Another species in the genus, *P. lametae*, is rare and known by poorly preserved fossils from the Maastrichtian-Paleocene marls of the Lamenta Formation, India. In Mexico, different authors reported fossils of this genus observed in rocks used in the construction of the archaeological site of Palenque, Chiapas. Since 2008, a joint INAH-UNAM project allowed the collection of numerous similar specimens in the Danian-Paleocene marine deposits belonging to the Tenejapa-Lacandón Unit, in the Belisario Domínguez and División del Norte quarries, near Palenque. The osteological features of these new specimens corroborate their belonging to *Pycnodus*. A meristic-morphometric analysis shows that the fossils of *Pycnodus* from Palenque represent a new species that differ from *P. apodus* due to the size and number of elements of the anal and dorsal fins, the predorsal proportion of the body, the composition and size of the caudal peduncle, and the number of dorsal and postcloacal scutes, among other features. The new species is important because it complements the evolutionary and biogeographical history of the genus and the tribe Pycnodontini, since this taxon is the oldest, most abundant, and best-preserved representative of the genus.





## ABYSSAL BENTHIC FORAMINIFERAL RESPONSE TO THE ENIGMATIC MIDDLE EOCENE CLIMATE OPTIMUM (IODP SITE U1511, SOUTHWEST PACIFIC)

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### Keywords

benthic foraminifera, agglutinated, Eocene, SW Pacific, Paleoecology

The Middle Eocene Climatic Optimum (MECO, ca. 40 Ma) is a global warming event that interrupted the gradual cooling trend of the Eocene during ~500 ka. Marked by a negative  $\delta^{18}\text{O}$  excursion in bulk sediment and benthic foraminifera, an increase in atmospheric  $\text{pCO}_2$  and shallowing of the carbonate compensation depth (CCD), it is considered an enigmatic event. The onset of the MECO was gradual and followed by a rapid return to pre-event conditions, while the onset of other Eocene warming events was rapid and followed by a gradual return. Furthermore, its onset does not coincide with a global negative carbon isotope excursion in marine carbonates, and carbonate dissolution in the deep sea was greater than expected. The study of the MECO is essential to unravel the relative role of changes in carbon flux vs. warming on the ocean floor, but there are only a few studies dealing with its effects. We carried out a quantitative study of benthic foraminiferal assemblages across the MECO at abyssal International Ocean Discovery Program Site U1511, in the Tasman Sea. Eocene sediments were deposited below the CCD, and calcareous microfossils are absent but agglutinated benthic foraminifera are well preserved. Here we present for the first time the benthic foraminiferal turnover across the MECO at abyssal depths. Assemblages display low diversity throughout the study interval (~15 taxa), and the abundance of the opportunistic species *Spiroplectamina spectabilis* peaked during the event. Our results indicate environmental instability at the seafloor during the MECO.





## ASSESSING THE VALIDITY OF THE SPANISH PLEURODIRAN TURTLE *NEOCHELYS ZAMORENSIS* CONSIDERING SHELL MATERIAL FROM ITS TYPE LOCALITY

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### Keywords

Duero Basin, Zamora Province, Lutetian, Testudines, Podocnemididae

*Neochelys* is the podocnemidid turtle recognized as the most abundant and diverse in Europe. This pleurodiran taxon is exclusive to the Eocene record. The youngest defined species correspond to Spanish middle Eocene representatives, which were defined several decades ago in the Duero Basin (Central Spain). One of them is *Neochelys salmanticensis* from the Bartonian of the Salamanca Province. Knowledge about this species has been remarkably improved by recent studies analyzing the anatomy and variability of its shell. However, the other Spanish representative (*i.e.*, *Neochelys zamorensis* from the Lutetian of the Zamora Province) is poorly known. Thus, it lacks a valid diagnosis and, considering the current knowledge about this genus, no comparisons with other species have been made. The aim of this work is the detailed analysis of the shell anatomy of *Neochelys zamorensis*. To this end, several specimens from its type locality (*i.e.*, Sanzoles) are analyzed in detail, including both the shell corresponding to its holotype and unpublished shells and articulated shell fragments (corresponding to both the carapace and the plastron). In this way, its validity is confirmed, and a new diagnosis is proposed.





## STUDY OF FOSSIL AND RECENT FORAMINIFERA AND MARINE MICROPLANKTON FROM THE BEAGLE CHANNEL (SOUTH AMERICA) USING STATISTICAL ANALYSIS

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### Keywords

Statistical analysis, Benthic foraminifera, Marine palynomorphs, Tierra del Fuego, Argentina

A comparative study on the distribution of Holocene and recent benthic foraminifera, as well as organic-walled microplankton (mainly dinocysts and acritarchs) was performed in samples from both sediment surface and excavation carried out from the surface down to 70 cm-depth in the Beagle Channel, using multivariate analyses. Late Holocene (group A) and recent (group B) samples were used to perform a non-metric multidimensional scaling (nMDS) analysis, an analysis of similarities (ANOSIM), and a similarity percentage (SIMPER) analysis. The nMDS analysis showed significant dissimilarity between groups A and B, as well as dissimilarity within group B (subgroups B1, B2, B3, and B4). According to ANOSIM and SIMPER analysis, this dissimilarity is due to the contribution of species with greater affinity for either the fossil (3 foraminifera and 4 marine microplankton) or recent (3 foraminifera and 2 marine microplankton) samples. The foraminifera species with greater affinity with the Group A are *Criboelphidium excavatum*, *Elphidium macellum*, and *Elphidium alvarezianum* and the marine microplankton are *Brigantedinium simplex*, *Palaeostomocystis subtilithecra*, *P. fritilla*, and *B. cariacense*. On the other hand, the foraminifera species with a greater affinity with the group B are *Cibicoides dispars*, *Buccella peruviana*, and *Cibicides aknerianus* and the marine microplankton species are *Pentapharsodinium dalei* and *Selenopemphix quanta*. This integrated analysis is useful in demonstrating the similarities and/or dissimilarities in the distribution of samples based on the relative abundance of taxa.





## EQUIDS FROM THE PLIOCENE–PLEISTOCENE SITES OF EASTERN CARPATHIAN FORELAND (EASTERN ROMANIA)

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### Keywords

*Proboscidea*, Măluşteni, Early Pliocene, Pleistocene, Romania

The Eastern Carpathian Foreland is located on the Moldavian and Scythian platforms, and part of the Dobrogean sector, extending to Ukraine and the Republic of Moldova. The Pliocene and Pleistocene units that crop out in this area yielded numerous vertebrate remains including various equid specimens. Here, we present a taxonomic reassessment of the equid specimens collected from Bereşti, Măluşteni, Rateşu Cuzei, and Olteneşti, which are currently found at the University of Bucharest and the 'Alexandru Ioan Cuza' University of Iaşi. The Early Pliocene assemblages from Măluşteni and Bereşti include some rare teeth and limb bones belonging to *Proboscidea crassum*. The Late Pliocene–Early Pleistocene material from Bereşti includes a right maxilla and a lower tooth belonging to *Equus stenonis*. Also, some isolated equid teeth from Măluşteni and Bereşti are assigned to *Equus ferus*, which documents the presence of the Late Pleistocene in the area, in addition to the better-known Pliocene deposits. The Middle Pleistocene material from Olteneşti is represented by teeth and postcranial bones assigned to *Equus mosbachensis*. The Late Pleistocene material from Rateşu Tecuci includes dental and postcranial elements assigned to *Equus ferus* and *Equus hydruntinus*.

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## NEW CRANIAL REMAINS OF *DECENNATHERIUM REX* CALVES FROM BATALLONES-10 (LATE MIOCENE, IBERIAN PENINSULA)

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### Keywords

Giraffidae, Ossicone, Variability, Ontogeny, Cerro de los Batallones

The recovery of new cranial remains of *Decennatherium rex* Ríos, Sánchez and Morales, 2017 from the Late Miocene (MN10, late Vallesian) deposits of the site Batallones-10 from the Madrid Basin (Valdemoro, Spain) sheds light on the ontogenetic variability of this extinct giraffid, as most of the remains found usually belong to adult individuals. The new material, recovered during the 2022 campaign, comprises two hemimandibles and a maxilla belonging to the same juvenile individual, and a juvenile ossicone which likely belongs to a different individual. The dental material recovered represents one of the youngest giraffid specimens in the entire Batallones complex sites sample, with an estimated age of no more than seven months old according to the eruptional stage of its cheekteeth based on studies made in *Giraffa*. The ossicone recovered has the same proportions and shape of an adult male of the species, with an oval cross section and a blunt tip, but the size is much smaller in comparison. This is also seen in the extant *Giraffa* where juvenile ossicones are identical in proportions but smaller than those of adults. Our specimen is detached, as it is expected for ossicones of young individuals, as they do not fuse until later in life. This new material expands our ontogenetic knowledge of giraffids as it includes the first giraffid calf ossicone recovered from the Iberian record.





## MICROVERTEBRATE FOSSILS FROM THE MIOCENE LOCALITY OF DUNERA, PATHANKOT DISTRICT, PUNJAB, INDIA: BIOSTRATIGRAPHIC IMPLICATIONS

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### Keywords

Siwalik, Microvertebrate, Nagri Formation, India

The Dunera (Pathankot district of Punjab State, India) region of Siwalik is well known for its megavertebrate assemblage, but no microvertebrate fossils have yet been discovered. The estimated age of this area has not been available due to the absence of age-diagnostic fauna in the locality. Recently, a diverse microvertebrate fossil has been recovered from a locality exposed nearby the Dunera town, representing all isolated teeth. The materials are identified as rodents such as Murinae indet. (*Progonomys hussaini*), the ctenodactylid (*Sayimys sivalensis*), the cricetid (*Democricetodon fejfari*) and the sciurid (cf. *Tamias urialis*); lizard such as Acrodonta (cf. *Uromastyx*, Agamidae indet.), Scincoidea (Scincidae indet.); fishes such as Cypriniformes (Cyprinidae indet.), Perciformes indet.; crab (Decapoda, Sartoriana indet.). Micromammals, especially rodents, contain numerous time-sensitive species, and have thus been heavily used in biostratigraphic analyses because they can help accurately estimate the geological age at a high resolution for localities where other geochronological dating methods are not available. The rodents here are documented for the first time in this region. Based on the biostratigraphic ranges of these rodents from well-dated Siwalik of Pakistan, the present study locality is placed between ~11-10 Ma that may be equivalent to the lower Nagri Formation (Late Miocene).





## THE OLDEST VIZCACHAS (*LAGOSTOMUS*, *CHINCHILLIDAE*) FROM CENTRAL ARGENTINA

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### Keywords

Caviomorph rodents, taxonomy, Cerro Azul Formation, Late Miocene–Early Pliocene

Lagostominae (Rodentia, Caviomorpha, Chinchillidae) includes a single living species, the plains vizcacha *Lagostomus maximus*, but representatives of this subfamily are registered since the Early Miocene. Different extinct species of *Lagostomus* are recorded in southern South America, in Argentina, Bolivia, Uruguay and southern Brazil. In levels of Cerro Azul Formation (late Middle Miocene–Early Pliocene) from central Argentina, two species were recognized based on specimens from two localities, *L. telenkechanum* (Arroyo Chasicó, Buenos Aires Province; Chasicóan) and *L. pretrichodactyla* (Salinas Grandes de Hidalgo, La Pampa Province; Huayquerian). New materials (485 specimens, of which 231 specimens were measured and described) recovered from 19 localities from Cerro Azul Formation are analyzed here. The systematic evaluation is based on dental characters (measurements and morphology). The anteroposterior diameter of the molariforms is the measurement that better shows differences between species, reflecting the greater compression of *L. telenkechanum*. This analysis supports the coexistence of both species in ten assemblages of this unit. From Arroyo Chasicó, Cerro La Bota and El Durazno only *L. telenkechanum* was registered, and from Algarrobo del Águila, El Guanaco, Don Mariano and Caleufú only *L. pretrichodactyla*. The studied sample includes thirteen specimens interpreted as juvenile individuals, which can only be determined as *Lagostomus* sp., as it happens with several incomplete remains in all the assemblages. Juvenile individuals are identified by their small size, immature bone, emerging teeth, p4 with globose morphology, and with very marked hypoflexid. This record of *L. telenkechanum* and *L. pretrichodactyla* increasing the geographic distribution of both species. Finally, the presence of two species coexisting in several localities of the Cerro Azul Formation, indicates a limited biostratigraphic value for the species of *Lagostomus* in the late Neogene of central Argentina.





## MIOCENE GIRAFFID OCCURRENCES FROM EASTERN CARPATHIANS FORELAND (ROMANIA)

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### Keywords

New Occurrences, Limb Bones, Paleobiogeography

The final uplift of Eastern Carpathians during the Miocene phases of Alpine orogeny caused the gradual south-eastern retreat of the Paratethys Sea. Among the various fauna that colonized the emerging land, the giraffids are only listed until now (Reghiu and Bacău localities). This paper assigns several limb bones to the giraffids of Khersonian-Maeotian age (Turolian). Due to the isolated and fragmented fossils, only *Helladotherium duvernoyi* is a certain presence being documented in Văleni and Fălcium outcrops. The proximal epiphysis of the left metatarsal shows the typical articular facets, but external and medial cuneiform are closer than usual. The astragalus matches the original description but shows a wide and shallow fossa. Two other limb bones are kept in the open nomenclature. The proximal epiphysis of the right metacarpus (Crețești locality) exhibits a triangular facet for hamate bone representing less than half of the irregular kidney-like facet for trapezoid-capitate bone. The synovial fossa is closed. The pyramidal rise is obvious in the proximal part. The distal epiphysis preserves moderate epicondyles. The metatarsal of Pogana locality shares similar kidney-shaped external cuneiform and naviculoboidium articular facets. The medial cuneiform is largely eroded but it seems rounded and not in contact with the external cuneiform. The rudiment of the metatarsal prolongs on the medial side by a strong rudiment. There are no pygmaios (?*Decennatherium*). All biometric parameters fall in the plotting diagrams of the species variability. These Turolian giraffids connect the occurrences from the Aegean area to the Eastern European lands (Ukraine, Republic of Moldova).





## NEW INSIGHTS ON CETOTHERIID (CETACEA: MYSTICETI) REMAINS FROM THE DACIAN BASIN (SOUTHERN ROMANIA)

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### Keywords

Romania, Miocene, Dacian Basin, Cetotheriidae

The Paratethys Sea was home to the Cetotheriidae, a family of small to medium sized Neogene baleen whales. This family included most baleen whale taxa that lived in the Eastern Paratethys during the Middle and Late Miocene. As such, fossil remains of Cetotheriidae are found throughout the basins of the Paratethys, the Dacian Basin (southern Romania) being no exception. Albeit old, dating from the beginning of the 20<sup>th</sup> century, reports on cetotheriid occurrences in the Dacian Basin are rare and their taxonomical and systematic assessment is outdated. Material pertaining to this group of marine mammals is often referred to the species *Cetotherium priscum*, presently regarded as *nomen dubium*. The aim of this work is to taxonomically assess fossil specimens from four institutional collections (National Geological Museum, "Grigore Antipa" National History Museum, Oltenia Museum, Craiova and Faculty of Geology and Geophysics) and to provide an updated geographical distribution of the fossiliferous localities from the Dacian Basin. The remains, collected from nine different Miocene aged localities, are represented only by postcranial elements, mostly vertebrae, and one humerus. Most specimens could only be identified as belonging to the family Cetotheriidae, only a few presenting morphological and dimensional features indicative of *Mithridatocetus* sp. The latter genus is identified for the first time in the Dacian Basin from four distinct localities.





## CETACEAN FOSSIL RECORD FROM THE NEOGENE OF THE WESTERN GUADALQUIVIR BASIN, SW SPAIN

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### Keywords

Cetacea, Miocene, Pliocene, Guadalquivir Basin, Strait of Gibraltar

During the Miocene era, the Guadalquivir Basin, previously known as the Norbetic Corridor, served as a connection between the Atlantic Ocean and the Mediterranean Sea. Due to this, as well as the opening of the Strait of Gibraltar during the lower Pliocene period, this area to the south of the Iberian Peninsula has since experienced a significant abundance in marine fauna, as well as the presence of both native and migratory species. The fossil record of cetaceans of the western Guadalquivir Basin is presented in this work. Mysticeti, known as baleen whales, are frequent, with several specimens with a large skeletal percentage preserved. Remains are mostly isolated post-cranial bones (vertebrae and rib fragments) and some jaw fragments. The study of some diagnostic elements, such as tympanic bullae, has made it possible to identify two of them at the species level, within the family Balaenopteridae, such as *Balaenoptera physalus* (the Fin Whale) and *Megaptera novaeangliae* (Yubarta). There is also a record of a Cetotheriidae skull. Odontoceti, or toothed whales, are much less common. The dental material has made it possible to identify five taxa, three related to sperm whales (Physeteridae), one to a family of extinct dolphins (Kentriodontidae), and another to the family of current dolphins (Delphinidae). The cetacean fossil record from SW Spain represents a significant contribution to our knowledge of marine vertebrate paleocommunities and their role in past food chains.





## PRELIMINARY ANALYSIS OF A NEW PHOCID RECORD FROM THE IBERIAN NEOGENE

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### Keywords

Pinnipedia, Phocidae, Miocene, Pliocene, Guadalquivir Basin

Pinnipeds (Carnivora, Pinnipedia) are a clade of marine mammals divided into three modern families (Otariidae, Phocidae, and Odobenidae) and two extinct families (Desmatophocidae and Enaliarctidae). Phocids (Phocidae) are also known as seals or true seals, as opposed to the so-called eared seals (Otariidae). The Miocene and Pliocene fossil record of phocids in the Iberian Peninsula is scarce. The area studied was located in Huelva, SW of Spain, in the old Norbetic Corridor (modern Guadalquivir Basin) that connected the Atlantic Ocean and the Mediterranean during the Miocene. A pelvis belonging to *Homiphoca* (Phocidae: Monachinae: Lobodontini) was described in 2018 from Lower Pliocene deposits. A new pinniped bone has recently been recovered in sediments from the Upper Miocene (Messinian) of the underlying unit in the same outcrop. It is an incomplete humerus, the distal half, which can be attributed to the Phocinae. The diaphysis is narrow and cylindrical, with a deltopectoral crest that rises rapidly and away from the distal end. The posterior face is very flat, without distinguishing the supinator crest. Although the study is in its initial phase, when comparing this bone to phocid taxa, differences were preliminarily noted with the extinct *Callophoca obscura*, *Homiphoca capensis* and *Pliophoca etrusca*, and the extant *Monachus monachus*, *Neomonachus schauinslandi* and *Neomonachus tropicalis*. Whereas similarities were noted with the extinct species *Gryphoca similis*, and the extant taxa *Pagophilus groenlandicus* and *Phoca vitulina*. This suggests the presence of two different lineages of phocids, establishing possibly the first fossil record of Phocinae in Spain.





## **BRASILIOCHOERUS STENOCEPHALUS (LUND IN REINHARDT, 1880), A LARGE EXTINCT PECCARY IN THE LATE PLEISTOCENE OF URUGUAY: A COMPARATIVE, ISOTOPIC AND PALEOECOLOGICAL STUDY**

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### **Keywords**

Comparative Morphology, Multivariant, Stable Isotopes, Sopas Formation



Tayassuids are conspicuous members of the present-days Neotropical mammalian communities (three extant species) and were represented by diverse taxa in the South American Pleistocene. In late Pleistocene sediments outcropping in Northern Uruguay (Sopas Formation, Sopas creek) (OSL age: 43 ky), an almost complete skull (FCDPV-3034) was found and referred to the extinct *Brasiliochoerus stenocephalus* (Lund in Reinhardt). We provide a morphological and morphometric comparative analysis, discuss the fossil co-occurrence with the extant *Tayassu pecari* (FCDPV-1057), and evaluate the first known isotopic results including mixing-model analysis to infer the feeding behavior of both peccaries and the paleoenvironment, including fauna associated. Bivariate and Multivariate analyzes considering *B. stenocephalus* and the three extant species were performed. The skull measurements show that *B. stenocephalus* is similar or larger than *Parachoerus wagneri* and both larger than *T. pecari* and *Dicotyles tajacu*. Considering dental measurements alone, *B. stenocephalus* shows a more similar size to *T. pecari* superposing the morphospace, which put in evidence the significance of skull measurements to characterize this extinct taxon. The  $\delta^{13}\text{C}$  suggests that *B. stenocephalus* and *T. pecari* had browser-feeding preferences, with a diet based mostly on C<sup>3</sup> plants (75% and 81% respectively) in forested savanna, probably including riparian wooded habitats. If  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  are taken together, it can be inferred that both fed mostly on the canopy frugivore range, including leaves and some floor plants. It supports the browser semi-open woodland lifestyle in a C<sub>3</sub>-C<sub>4</sub> grassland to open-canopy environments previously suggested and sustained by fauna associated.

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## FISHES, AMPHIBIANS AND SQUAMATES FROM THE EARLY PLIOCENE SITES OF BEREȘTI AND MĂLUȘTENI (EASTERN ROMANIA) – A REVIEW OF OLD BUT POORLY KNOWN MATERIAL

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### Keywords

Ichthyofauna, Herpetofauna, Early Pliocene, Romania

First described in the 1930s, the continental vertebrate faunas from the neighbouring localities of Berești and Mălușteni (Eastern Romania) remain to this day the most diverse taxonomically of the entire Pliocene of Romania. Although ectothermic vertebrate specimens were also collected, only the mammalian and chelonian taxa have so far been described in detail. Here, we present a taxonomic reassessment of the fossil fish, amphibian, and squamate specimens collected from Berești and Mălușteni, currently found at the University of Bucharest and the 'Alexandru Ioan Cuza' University of Iași. The assemblage from Mălușteni includes indeterminate acipenseriform postcranials, as well various cranial and postcranial elements assigned to cyprinids (*Rutilus robustus*, *Barbus* sp., *Scardinius ponticus*), esocids (*Esox moldavicus*, *Esox* sp.), and silurids (*Silurus soldatovi*, *Silurus* sp.). Squamates are represented by fragmentary vertebrae assigned to viperid and natricid snakes, and by the anguid lizard *Pseudopus pannonicus*. The assemblage from Berești is quite similar in taxonomical composition to the one from Mălușteni, including cyprinid (*Rutilus robustus*, *Rutilus* cf. *R. frisii*, *Rutilus* sp., *Scardinius ponticus*, *Barbus* sp.), esocid (*Esox moldavicus*, *Esox* sp.), silurid (*Silurus* sp.), and percid (Percidae indet.) fishes, viperid and natricid snakes, and the anguid *Pseudopus pannonicus*. In addition, one cryptobranchid vertebra and several elasmobranch specimens were found at Berești, but their different type of fossilization and wearing suggests that these specimens were redeposited from older sediments.

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## A NEW SKELETON OF *TITANOCHELON* FROM THE LATE MIOCENE (MN10) OF RONDA OEST DE SABADELL (VALLÈS-PENEDÈS BASIN, NE IBERIAN PENINSULA): TAXONOMIC IMPLICATIONS

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### Keywords

Testudinidae, Giant tortoises, Neogene, Vallesian, *Titanochelon richardi*

The taxonomy of giant tortoises (Testudinidae) from the Neogene of Europe is far from being settled and debates about their alpha-taxonomy have implications for reconstructing their phylogenetic relationships. In 2014, *Titanochelon* was erected to include many of these species, formerly included in *Cheirogaster*. However, the diagnosis of the type species of this genus (*Titanochelon bolivari*) is unclear because of its synonymization with *Titanochelon richardi*, originally described based on plastron remains from early Vallesian (MN9) layers from els Hostalets de Pierola and alternatively considered a distinct species based on roughly coeval cranial material from Ecoparc de Can Mata. We describe a new partial skeleton of *Titanochelon* from the late Vallesian (MN10) of Ronda Oest de Sabadell locality ROS-D6, which preserves the skull, the shell (carapace and plastron), and other postcranial elements. Based on cranial morphology, it is assigned to *T. richardi*, thereby enabling a more complete description of the species and a re-evaluation of the purported synonymy with *T. bolivari*. Our comparisons support *T. richardi* as a distinct species and that an emended diagnosis of *T. bolivari* might be required. Our results further confirm the record of *T. richardi* in MN10. Based on available evidence, *T. richardi* is recorded from the Vallès-Penedès and some inner Iberian basins between MN7+8 and MN10, while *T. bolivari* might be restricted to the Madrid Basin between MN5 and MN6. The new skeleton further offers the prospect to test the monophyly of genus *Titanochelon* in the future by means of a formal cladistic analysis.





## TRACING THE EVOLUTIONARY HISTORY OF THE FAMILY SCIAENIDAE (PERCOMORPHACEAE, EUPERCARIA) BY MEANS OF MACHINE LEARNING TECHNIQUE

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### Keywords

Sciaenidae, Variational Autoencoders, Fossil otolith, 2D images

The inconsistency between molecular dating and fossil records brings limitations to a better understanding of phylogeny and systematics. The family Sciaenidae is a prominent example, which has well-understood phylogeny and plenty of otolith fossil records, yet the inconsistencies remain unresolved. Otoliths are sensory structures in teleost fishes that may reflect adaptive advantages in evolution of teleost fishes, and their fossils further record fish adaptation in geological time scale. In this study, we aim to accomplish an integrated view of the Sciaenidae evolution by investigating the otolith of both extant and fossil specimens. Here, we applied a Variational Autoencoder (VAE) to a total of 1288 2D otolith image collections, which covered 46 of 69 extant Sciaenidae genera and 66 extinct Sciaenidae genera dated back to early Eocene (~54 Ma). The latent matrix of each otolith image exported from the properly trained VAE served as the quantification of the otolith morphology. Then the quantified otolith morphology was acquired to elucidate the morphometric diversity and character evolution for inferring a comprehensive view of the evolutionary history of Sciaenidae.





## EVOLUTIONARY FLEXIBILITY AND CONSTRAINT OF FISH OTOLITHS: A CASE IN SCIAENIDAE (CROAKERS)

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### Keywords

Geometric morphometrics, Fossil otoliths, 2D image, generalized Procrustes analysis

The integration of morphological traits and functional ability has long been a subject of interest in evolutionary study. The fish otoliths are ideal material to assess this issue due to their taxon-specific morphology and auditory-correlated function. Otoliths possess two distinct contours, outline and sulcus acusticus, which are believed to interact with distinct tissues in the auditory system of fishes. We conducted a study on the otoliths of Sciaenidae, a globally distributed nearshore fish family with prominent otoliths, to investigate variations between the contours. The Sciaenidae has evolved into more than 300 modern species and 69 genera since their first appearance in the early Eocene (~54 Ma), making it a highly diversified and well-represented family with abundant fossil records worldwide. We defined landmarks and extracted two contours from the images of modern and fossil otoliths (66 genera) and then employed geometric morphometrics (GM) technique to identify the variations. By investigating both fossil and modern sciaenid otoliths, our ongoing GM analysis may reveal evolutionary history and constraint of otoliths in this group.





## NEW FOSSIL REMAINS (LATE PLEISTOCENE) OF THE EXTANT SPECIES OF CAPYBARA *HYDROCHOERUS HYDROCHAERIS* (RODENTIA: CAVIOMORPHA: CAVIIDAE) FROM THE NORTHERN REGION OF URUGUAY

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### Keywords

Capybara, *Hydrochoerus hydrochaeris*, Late Pleistocene, Uruguay



A new fossil of a Hydrochoerinae rodent (Caviomorpha: Caviidae: Hydrochoerinae) from the Quaternary of the northern region of Uruguay is described. The analyzed material is an almost complete cranium (that preserves right M1, both M2, and both M3). It was found in the Sopas Formation (Late Pleistocene, radiocarbon ages range from approximately 33,000 to 12,000 yrs. BP) (Salto, Uruguay) in sedimentary facies composed of massive brownish mudstones with disseminated gravel clasts and carbonates. These facies were deposited by slumps (with occasional flows that deposited sand and gravel lenses) and then exposed to the surface in a dry and hot climate (paleosoils were formed, and carbonate was deposited). The specimen (FC-DPV 2934) is assigned to the taxon *Hydrochoerus hydrochaeris* based on quantitative analysis (comparing it with other Pleistocene Hydrochoerinae species) and diagnostic traits (M3 with 12 prisms, rostral area relatively wide, smaller proportions than *Neochoerus* and larger than *H. isthmius*). Bivariate analyses locate this individual along with the largest specimens of the extant *H. hydrochaeris* of the sample. According to the pattern of cranial sutures, it was an adult. This finding is the most complete fossil specimen of this species in Uruguay. The paleoenvironmental implications of this taxon are the presence of water throughout the year, dry ground with bush or forest, and vegetation such as grasses, sedges, and/or semi-aquatic plants. These interpretations are consistent with the information provided by sedimentary facies analysis and the paleontological inferences for other taxa of the Sopas Formation.

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Ataque de *Repenomamus* al nido de *Psittacosaurus*  
Navarro Guerrero Daniel  
Palaeoart Competition (2<sup>nd</sup> Prize, tie)



# General Palaeontology



**General Session**



## AQUATIC GIRAFFE AND POKÉMON'S – TEACHING OF EVOLUTION IN PRIMARY SCHOOLS USING PURPOSEFULLY-FRAMED PLAY

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### Keywords

palaeontological education, non-formal education, evolution

Fossil record show that life on Earth was different in the past, which is one of the best evidences for evolution. Despite this, it is scarcely represented in the curricula of primary schools. For different reasons in some countries the meaning of evolution in environmental education systematically decreases. A series of scientific workshops for children were designed to test whether evolution can be taught effectively for primary school pupils outside the school, in non-formal education. Workshops conducted during childrens' university course follow the so-called 'purposefully-framed play' methods. 33 groups, around 500 children participated in 1 hour meetings (4 different scenarios were used, but leading to the same conclusion). At the end of the workshop, participants were supposed to design new species that evolved from recent animal under certain conditions (adapting to climate change, defending against predators, effectively searching for food, etc.). Although some misconceptions appeared (e.g., rapid evolution in Pokémon style), they can be easily and quickly corrected thanks to the purposefully-framed play character of the workshops. Students mostly completed the task successfully, creating a set of fantastic, but accurate species, proving that evolution can be taught since the beginning of formal education and that purposefully-framed play can be used to teach about modern and fossil biodiversity.





## HOW TO CLASSIFY YOUR DRAGON: THE SYSTEMATIC REVISION OF DRAGONS OF THE DREAMWORKS CARTOON

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### Keywords

operative learning, dragons, introduction to taxonomy, ludic learning,  
science education



In 2010 the film production company Dreamworks Animation® produced a project titled "How to train your dragon", film adaptation based on the children's book series written by Cressida Cowell which tells the adventures of a group of Viking teenagers who train dragons. The project consists of three films, some television series, comics, and videogames. The protagonists Hiccup, Astrid, Fishlegs, Snotlout, Tuffnut and Ruffnut, using previous sources or writing new ones, make a classification of the dragons that they live with and identify the following classes: Boulder, Mystery, Sharp, Stocker, Strike, Tidal, Tracker, Fear. The classification made in this fictional world uses some terms borrowed from the Linnaean classification (i.e., classes, realms) but differs from it in terms of the methods used. The purpose of this work is to revise the classification of dragons using the proper techniques of Linnaean classification. During the 18<sup>th</sup> century, Carl Nilsson Linnaeus (1707 - 1778) proposed a classification of living and fossil organisms based on a hierarchy of increasingly vast groups. The smaller groups contain the individual species which are grouped into larger groups - the genera - and up through the families, orders, classes, phyla. This system is the current Science of Taxonomy and Systematics. In the present project the topic of Linnaean systematic classification has been made more imaginative and suitable for children of all ages. This fictional work was chosen because many dragons are shown, each with its own characteristics that lend themselves well to the type of proposed study.



## A REVIEW OF FAUNAL AND LITHOLOGICAL FACIES VARIATION IN ZANSKAR TETHYAN ZONE: IMPLICATIONS ON BIOSTRATIGRAPHY, PALEOENVIRONMENT AND INDIA-ASIA COLLISION

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### Keywords

Zanskar Tethyan Zone, Fauna, Lithology, Biostratigraphy, Paleoenvironment, India-Asia Collision



The Cretaceous-Eocene successions are well developed in the NW Himalaya along five E-W trending belts: the southerly Himalayan foothill belt and northerly Zanskar Tethyan Zone of the Indian Plate; and Karakoram Tethyan Zone of the Asian plate; and in the intervening Southerly Indus Suture Zone and northerly Shyok suture zone between the Indian and Asian plates. The Cretaceous-Eocene successions exposed in the Zanskar Tethyan and Indus Suture Zones have the most complete record of the India-Asia collision and preceding events. In the Zanskar Tethyan Zone, the dominantly marine Cretaceous-Lower Eocene succession is in continuation of the underlying older phanerozoic platform deposits of the southern Tethys facing to the north. This succession was deposited over a passive continental shelf at the northern margin of the Indian Plate. Earlier researchers have done significant work in the biostratigraphic zonation and lithostratigraphy of the succession. Yet, a lot more information can be derived from the region for solving the mysteries of the geological past. Our main focus in the Zanskar Tethyan Zone where Cretaceous and Paleogene marine sediments are exposed in NZB and SZB is to fill the knowledge gap. A multi-proxy study is required to refine biostratigraphic scheme, faunal and lithofacies change and subsequent paleoenvironmental conditions of the Zanskar Tethyan Zone with context to collision of India and Asia. Overall, these studies will be helpful in establishing a global biostratigraphic correlation, paleoenvironmental and tectonic events of India-Asia collision.



## FIRST FOSSIL EVIDENCE OF TRUNKS OF CYCADALES FROM MEXICO

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### Keywords

Cycads, Trunks, Veracruz, Mexico, Paleobotany

The broad paleobotanical fossil record in Mexico provides the opportunity to know the groups of extinct plants that inhabited our country and the related environmental conditions that prevailed at each geologic time. Nevertheless, fossils of Cycadales, are scarce in Mexican territory and they are restricted to date to some impressions of leaves corresponding to genera *Taeniopteris* and *Bjuvia* from the Jurassic limestones of Oaxaca and Chiapas regions. In this work, we present the first evidence of trunks of Cycadales in Mexico, which consist of columnar-shaped mature stems, more than two meters in diameter preserving the vestiges of the leaf scars perfectly visible.





## DEMINERALIZATION OF MEDIUM AND MEGAMAMMALS BONES FROM PAMPEAN REGION (ARGENTINA AND URUGUAY)

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### Keywords

Collagen, Paleoecology, Extinction, Conservation



The causes of the extinction of Pampean taxa are still controversial. One of the main problems is the irregular conditions of collagen preservation, which makes it difficult to understand diets and paleoenvironments. For that, this contribution will detail two demineralization methods applied to bones of medium and megamammals in order to obtain collagen for stable isotope analysis ( $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ ). Bones of Xenarthra, Carnivores and Ungulates (N=25) from the last 30.000 YBP were taken from 9 locations. Collagen was extracted in 11 samples but only 3 provided isotopes (2 Equidae and one *Glyptodon*). For the first method 15 samples were diluted in 0.2M hydrochloric acid (HCl) and then in 0.1 M sodium hydroxide, then into the oven (60°). Only 6 bones did not dissolve and 2 were measured. Demineralization process was slowed for the second method. Twenty-five samples (the aforementioned 15 plus 10 new) were demineralized at 0.5 M HCl at room temperature, then in the refrigerator at 4°. Nine were put in the oven (70°) with distillate water and 3 drops of 0.5 M HCl. After approximately 15 days, 7 bones yielded collagen (5 new and 2 had yielded in the first try also). One provided  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  and 5 only  $\delta^{13}\text{C}$  (one was not measured). According to this and other studies, bone collagen is affected by humidity and temperatures of the Late Pleistocene and Holocene in this open-air region. An alternative is to measure the apatite fraction, a method insufficiently used in fossils of this chronology in the region.



## REASSESSMENT AND NEW RECORDS OF PLANT FOSSILS FROM THE PERMIAN-TRIASSIC LOS MENCUCOS GROUP (PATAGONIA ARGENTINA)

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### Keywords

Paleobotany, Pleuromeia, Stratigraphy, Post Extinction, Recovery



The outcrops located to the north and west of Los Mencucos locality (Río Negro Province, Patagonia, Argentina) comprise a complex sequence of volcanic and sedimentary rocks known as the Los Mencucos Group. This sequence, which is divided into the Puesto Tscherig, Puesto Vera, and Sierra Colorada formations, dates from the Lopingian to the Lower Triassic. The first two formations contain a rich fossil record, including tetrapod tracks and plant fossils. Although the fossil-bearing strata of the Los Mencucos Group have been known for over fifty years, their precise geographic and stratigraphic provenance, as well as their age, remain poorly understood. Recent field trips have allowed us to identify the location of the fossil strata and to discover new fossil sites and plant fossil samples. The paleofloras have been organized into four fossiliferous strata, which are FS1 from the Puesto Tscherig Formation, FS2 and FS3 from the Puesto Vera Formation, and FS4 from an unnamed lithostratigraphic unit. The main results are the occurrence of Pleuromeialelean stems and herbaceous lycophytes; the first record of palynomorphs; the presence of asterothecaceous fern leaves; and the discovery of permineralized woods and trunks from new localities. The new paleobotanical assessment, together with the latest stratigraphic and geochronological data, allows us to conclude that FS1 corresponds to the upper Lopingian, FS2 and FS3 can be assigned to the Lower Triassic, and FS4, most likely, to the Carnian. This improves the characterization of the floristic change across the Permian-Triassic boundary in Argentina and Southwestern Gondwana.



## EXPLORING MORPHOLOGICAL DISPARITY IN THE CASSIDULOIDA (ECHINODERMATA, ECHINOIDEA) USING GEOMETRIC MORPHOMETRICS

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### Keywords

Echinoids, Landmarks, Mouth Shape, Extinction Selectivity, Macroevolution



Cassiduloids are irregular echinoids with an expansive fossil record and few modern representatives. They originated in the Marine Mesozoic Revolution and reached their peak diversity in the Eocene (56–40 Mya). Since then, species diversity has been sharply declining. There is no agreed-upon source for this decline, but it is hypothesized to be related to their remarkably conserved morphology and lack of ability to innovate. Their shape variation, however, has never been quantified. To quantify the morphological disparity of mouth shape among cassiduloid families and through time, we compiled a dataset with ~350 two-dimensional images with representatives from all families, both fossil and extant. Five landmarks and 60 semi-landmarks were plotted on images using tpsDig. Geometric morphometrics and statistical analyses were performed on aligned landmarks using the R package geomorph, and a morphospace was constructed using Principal Component Analysis. Mouth shape was significantly different among families (Procrustes ANOVA,  $p < 0.001$ ) and through time (Procrustes ANOVA,  $p < 0.001$ ). Instead of extinction selectivity across the K-Pg boundary, the data shows an expansion of morphospace that continues to the present, contradicting the hypothesis of conserved morphology, at least with regards to mouth shape. This study is part of a project to quantify morphological disparity in cassiduloids. The K-Pg mass extinction was selective against round body shape, but petal shape also displayed a diversification trend across the boundary and throughout the Cenozoic. This project will pave the way for understanding why cassiduloid diversity has been dropping throughout the Neogene and why they are not yet extinct.



## ASSESSING THE POTENTIAL OF HIGH-RESOLUTION SYNCHROTRON MICROTOMOGRAPHY TO DOCUMENT THE PRESERVATION OF INSECTS IN AMBER

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### Keywords

Amber, Semi-quantitative, Synchrotron-Microtomography, Taphonomy

Preservation in amber is truly exceptional because it allows for the retention of fragile organisms and very labile tissues in three dimensions and in fine details, including some ultrastructural features and remains of endogenous organic molecules of physiological relevance. However, the observation of differences between fossil deposits and taphonomic studies have shown that preservation in resin is very heterogeneous regarding the chemical composition of the original resins. For resins, as in other preservation settings, the role of maturation and diagenesis in the fossilization process is poorly known. In a series of recent experiments, we assessed the potential of synchrotron microtomography with submicrometric resolution to non-destructively document both morphological and chemical changes associated with preservation of insects in resins. Here we will present early results from an experimental taphonomy protocol on fruit flies (*Drosophila melanogaster*) trapped in resins (epoxy and two natural resins from Araucariaceae) then heated at different temperatures up to 250°C to simulate diagenetic alteration. We use the semi-quantitative possibilities of synchrotron X-ray tomography through the evaluation of attenuation coefficients (calculated from the grey values of the tomographic slices) to evaluate changes in tissue density as a function of temperature. We revealed a decrease in density with thermal alteration for the cuticle in all resins, and an increase in density for the eyes in the two natural resins. More than just highlighting the potential of quantitative synchrotron microtomography to characterize physico-chemical changes associated with preservation in amber, we will also discuss how these experiments question current thermal maturation protocols.





## A METHODOLOGICAL FRAMEWORK TO TEST COMPETING HYPOTHESES ON THE NATURE OF ORGANISMAL EVOLUTION

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### Keywords

Evolution, Contingency, Determinism, Marine Tetrapods



The long-term patterns and processes of evolution is a key topic in evolutionary research and the debate over the contingency vs. determinism in evolution has occupied both biologists and palaeontologists alike for decades. Evolutionary history is replete with parallel natural evolutionary experiments from which general nomothetic principles can be gleaned. Among the most powerful of these natural experimental systems is the evolutionary transition to life in water by tetrapods, a phenomenon that has happened more than 30 times independently over different lineages. The recent emergence of new computational techniques in palaeobiology, for visualizing and analysing specimens digitally and in three dimensions as well as the development of novel tools for statistical computation, provides for the first time the opportunity to perform rigorous computational and physical examination to explore all these aspects. Here, we present a methodological pipeline based on a novel combination of state-of-the-art techniques in palaeobiology, including computational fluid dynamics, laser scanning, non-destructive X-ray computed tomography, geometric morphometrics, phylogenetic comparative methods and Pareto optimality analysis, in order to address the morphological diversity and disparity of extinct and living marine tetrapods from a functional, ecological and developmental point of view within temporal and phylogenetic frameworks. The ultimate goal of this methodological framework is to test competing hypotheses (contingency vs. determinism) on the nature of organismal evolution in marine tetrapods



## COMUNICAÇÕES GEOLÓGICAS - A 140 YEARS OLD PALAEO COMMUNICATION TOOL

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### Keywords

Journal, Bibliography, Fossils, Database, Science Heritage



Before the appearance of the digital tools necessary for online science communication to become the norm, researchers primarily relied upon printed scientific journals to spread science novelties. Older publications are thereby the starting point for any bibliographic search and, therefore, a key element to the Portuguese Fossil Database. Thus we needed to retrieve as much information as possible from them. From the literature analysis, we have struggled to identify a national science journal that withstood time other than Comunicações Geológicas, published by LNEG (National Laboratory of Energy and Geology). With 83 of the 109 issued tomes featuring palaeontological research, this journal published approximately 380 articles on or related to Portuguese Palaeontology. These tomes mainly include wide-scope studies and the description of new fossil species. Through the analysis of LNEGBASE (LNEG bibliographic database) and comparison with the literature featured on the Portuguese Fossil Database, we have observed a significant impact of Comunicações Geológicas in reporting national palaeontological studies from 1883 to 2023, corresponding to almost 20% of our listed bibliography for the same period. Also, despite the current trend to channel scientific publications to renowned international journals, this pioneering journal has overcome a drastic drop in the volume of palaeo-related articles of the new millennium, with a steady recovery since 2010. This year marks the 140<sup>th</sup> anniversary of Comunicações Geológicas, making this one of the most enduring science journals still to feature Portuguese palaeontological studies and proving to be an essential communication tool for national findings.



## PORTUGUESE FOSSIL DATABASE: TWO YEARS OF DATA GATHERING

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### Keywords

Fossil, Literature, Taxa, Outcrops, Portugal

With more than two centuries of palaeontology research focused on material found in Portugal, and a growing research community dedicated to the subject, the absence of platforms dedicated to gathering, organizing and sharing the published data continues to pose a problem. The Portuguese Fossil Database was created two years ago, in May 2021, as a solution to this problematic. Since then, we have fed the growing database through an intense bibliographic search and analysis effort. We here provide an update from the preliminary results presented at the 3rd Palaeontological Virtual Congress. With an improved team and 24 months of data gathering and harmonization, the total number of fossil occurrences is now 8.3 times higher, surpassing the mark of 17,000. We completed the analysis of 545 publications out of a total of 2,301 listed, dwarfing the 65 publications out of 709 presented in the last edition of this congress. With the task of screening the 4,103 taxa listed so far, we have identified 281 species first described in Portugal. Regarding the provenance of the Portuguese fossil material, we have geographically pinpointed 526 fossiliferous outcrops and listed more than 8,500 fossil occurrences with GPS coordinates associated. Although there is still plenty of work ahead, it is now possible to make preliminary observations on data sets such as the taxonomy repartition and the geographic distribution of fossil occurrences in Portugal.





## DEVELOPING THE APP “DINOS OF BRAZIL”

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### Keywords

Android, Mobile, Dinosaur, Technology



One of the most common habits of this century is to spend hours on the cell phone using some application. Facing this situation, the use of technologies is an ally in scientific dissemination, more specifically about knowledge of Brazilian paleontology. Mobile applications are one of the most effective means of communication with the general public, because most people have a smartphone. Thus, this work presents the development processes of the Dinos of Brazil application, available for all platforms with Android operating system. To achieve the objectives of the work, the activities were divided into three stages: planning, research, and creation. In the first stage, the scope of the project was defined, where it was decided that all 53 Brazilian dinosaurs and their most relevant characteristics would be listed, such as size, weight, and period lived. The research was carried out in scientific databases, looking for the most recent publications on Brazilian dinosaurs. The creation of the application was done on the Fabapp platform, using the photo album structure, listing paleoarts and information in a synthetic way. So far it has been noticed that most of the information about dinosaurs is not accessible and simplified in scientific articles, but rather in journalistic portals and social media. In this case, the Dinos of Brazil application intends to present clearly and uncomplicated information about all Brazilian dinosaurs, whenever a new dinosaur is described. This project is still in its final development phase and is expected to be completed by the end of the first semester of 2023.



## BURIAL POTENTIAL OF OPHIUROIDS UNDER INTRA AND EXTRABASINAL TURBIDITES

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### Keywords

Escape Postures, Preservation Potential, Vagrant Echinoderms, Experimental Taphonomy, Freshwater-Rich Sediments



The ophiuroids are a group of echinoderms which are rarely preserved as fossils. This is mainly due to the low fossilization potential of their skeletons, which quickly disarticulate after death. However, an under-explored cause could also be the free-living habit of these organisms, which makes them more able to escape many burial events. Based on it, the present study focuses on burial experiments with modern ophiuroids to assess the escape of vagrant echinoderms under different depositional conditions. For this, specimens of *Amphipholis januarii* were collected in the Paranaguá Estuarine Complex, southern Brazil, and acclimated in a 40-liter marine aquarium with an internal ramp. The escape behavior of live ophiuroids (10 per experiment) was monitored for 24 hours under artificial sedimentation of muddy turbidites, considering changes in interstitial fluid (fresh or saltwater) and deposited bed thickness (1, 5, or 10 cm). All specimens escaped within the first few minutes after deposition of 1 cm beds, regardless of the interstitial fluid. All ophiuroids still escaped quickly under a 5 cm bed with interstitial salt water, but only 4 specimens escaped after 10 hours under a 5 cm bed with interstitial fresh water. In turn, no escape was documented after the deposition of 10 cm beds, although vertical excavations of up to 5 cm were observed in the muddy bed with interstitial salt water. As a result, these experiments suggest a substantially higher potential for burial under extrabasinal turbidites, hindering the escape of vagrant echinoderms due to numbing by interstitial fresh water.



## EFFECT OF TEMPERATURE DURING THE PHYTOLITH EXTRACTION PROCESS

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### Keywords

Phytolith, *Arundo donax* L., Bilobate, Calcination

The present work reveals the response of bilobate phytoliths in leaves of *Arundo donax* L. treated by calcination in four thermal ranges: 500°C, 650°C, 800°C, and 950°C. The main objective of this abstract was to analyze whether there is a change in the size and/or shape of phytoliths extracted at different calcination temperatures. For this purpose, morphotype prospection was carried out by scanning electron microscopy (SEM) and the application of x-ray energy dispersive spectroscopy analysis (EDS) to characterize the elemental atomic components on the surface of the silicophytoliths. In addition, an analysis of morphometric variables of size and shape such as length, width, perimeter, area, convex perimeter, convex area, shape factor, roundness, convexity, solidity, and aspect ratio was performed. The phytoliths association was characterized by elongate, bulliform flabellate, bilobate, polylobate, cross phytoliths, and stomata structures, both unicellular and multicellular. Bilobate morphotypes were selected for the above-mentioned analyses because of their high frequency of occurrence in the samples. Bilobate phytoliths processed at 950°C, showed changes in colouring and alterations in shape indicated by high values of convexity, solidity, shape factor, and roundness, and in size represented by a reduction in perimeter, which is indicative of size reduction, increased sphericity, and convexity of the morphotypes. SEM observation and SEM-EDS analysis showed silica loss in phytoliths processed at 950°C. The present work contributes to the methodological knowledge of processing plant material for phytolith extraction, demonstrating that the calcination temperature should not exceed 800°C.





## THREE-DIMENSIONAL DIGITIZATION OF PHYTOLITH MORPHOTYPES

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### Keywords

Phytolith 3D, Modelling, Sculpting, Blender



The continuous development of 3D digitization and modelling tools has allowed their application in various scientific fields, including palaeontology, with benefits for the study and exposition of paleontological materials. Phytoliths are silica biominerals that form as deposits of hydrated amorphous silica in inter- or intracellular spaces of plant tissues. Phytoliths have intrinsic production characteristics related to environmental and physiological conditions, so they can be good indicators of old plant cover and environmental conditions. The objective of this abstract is to present two methods for digitizing phytoliths as three-dimensional models from two-dimensional images using freely available software. The first method is the bubble model using the Dust3D software and the second is the sculpting mode provided by the Blender software. The bubble model uses a microscope photograph or vector sketch as a guide to place nodes/bubbles which when connected form three-dimensional model of the phytolith. On the other hand, Blender's sculpting mode is a process of modifying the specific area of a base object using the brush tool that manipulates the geometry of the area of influence of the brush tool. It is important to note that the first method bubble, produces a model with little surface and colour detail. The second method, Blender, produces more specific colour and texture detail. As a result, three-dimensional models of the bulliform flabellate, blocky, rondel, saddle, globular echinate and globular psilate phytoliths have been produced. These proposals effectively achieve three-dimensional modelling that allows an understanding of the variety of phytolith morphotypes.



## UNRAVELING THE PALEOCLIMATIC, PALEOENVIRONMENTAL AND PALEOBIOLOGICAL CHANGES ACROSS 1MYR OF THE CRETACEOUS-PALEOGENE TRANSITION

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### Keywords

Deccan volcanism, Chicxulub impact, planktic foraminifera, mass extinction, climatic events



The 1 Myr interval across the Cretaceous/Paleogene boundary (KPB) is a brief period of Earth's history during which several remarkable events took place: the Chicxulub impact (~66 Ma), massive volcanism of the Deccan Traps (~66.3–65.6 Ma), and the KPB mass extinction event (~66 Ma). Other relevant events were the Late Maastrichtian Warming Event (LMWE; 66.25–66.10 Ma), the Dan-C2 (65.8–65.7 Ma), and the Lower-C29n event (LC29n; 65.48–65.41 Ma). Here we evaluate the climatic, environmental and biological changes during these events and their relation to Deccan volcanism, the Chicxulub impact and orbital forcing. We carried out high-resolution planktic foraminiferal and geochemical analyses from internationally renowned sections of the KPB, including Caravaca and Zumaia (Spain), El Kef (Tunisia), and ODP-1262 (South Atlantic). All proxies have been calibrated with an orbitally tuned age model and compared with the latest eruptive models for the Deccan Traps. No relevant paleoenvironmental changes have been recognized during the LMWE, nor in the last 100 kyr of the Maastrichtian, nor during the early Danian events Dan-C2 and LC29n. Conversely, in all the studied localities, we have identified a bloom of opportunistic triserial guembeltriid *Chiloguembelitria* in the early Danian (~65.9 Ma), which covariates with an increase in aberrant planktic foraminifera and suggests a resurgence of environmental stress. This environmental stress episode is correlated with an anomaly in the Hg/TOC ratio (~65.9 Ma) at ODP-1262, supporting a cause-effect relationship with the Deccan Traps mega-eruptions that occurred during the emplacement of the Ambenali Fm. in the early Danian.



## CHARACTERIZATION AND EXPERIMENTAL TREATMENT OF PYRITE OXIDATION ON INVERTEBRATE FOSSILS

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### Keywords

Conservation, Preservation, Natural History Collections, Paleontology, Iron Sulfide



Pyrite oxidation is an ongoing problem that has plagued museums and collection facilities for over a century. Pyrite can oxidize spontaneously with oxygen and water in the air:  $4\text{FeS}_2 + 13\text{O}_2 + 2\text{H}_2\text{O} \rightarrow 4\text{FeSO}_4 + 2\text{H}_2\text{SO}_4 + 2\text{SO}_2$ . The University of Michigan Museum of Paleontology Invertebrate Division contains millions of pyritized specimens from the Middle Devonian. A subset of 200 atrypid brachiopods (low-Mg  $\text{CaCO}_3$  skeletons) was used to employ treatment methods to determine the most effective means for removing the byproduct material — continuous oxidation of pyrite can destroy irreplaceable specimens. Approaches included mechanical treatment and submersion in water, hydrogen peroxide, lithium aluminum hydride, ethanolamine thioglycolate, and pyridine. We evaluated the efficacy in terms of cost per specimen and visible improvement and removal of byproduct. Two rounds of mechanical treatment with a brush and compressed air is most cost effective but not as efficient at removing the byproduct. Hydrogen peroxide baths were effective in reducing the sediment and byproduct from the surface but also caused cracking and harm to the specimens. Ethanolamine thioglycolate was effective in treatment but costly in terms of material required. Lithium aluminum hydride was effective, but the corresponding danger makes the treatment method impractical. Pyridine treatments were successful and a combination of pyridine and manual scrubbing provided the best results. The specimens are stored in a climate controlled room and the results will be re-evaluated four times annually to identify the emergence of any new oxidation products.



## INTEGRATING FOSSILS IN THE TOTAL-EVIDENCE PHYLOGENY OF THE ROVE BEETLE SUBFAMILY STAPHYLININAE (INSECTA: COLEOPTERA: STAPHYLINIDAE)

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### Keywords

Phylogenetics, Palaeobiology, DNA, Morphology



The rove beetle subfamily Staphylininae comprises approximately 7000 described extant and fossil species the latter dating back to the Early Cretaceous. Staphylininae include many of the common large rove beetles that are predators in extant ecosystems. Whilst they mainly occur in leaf litter and other terrestrial detritus, they have also evolved several remarkable lifestyles, such as being mutualistic with mammals or capable of withstanding extended periods of time submerged in salt water. During the last 15 years the Staphylininae have received substantial attention with regards to their phylogeny, especially based on molecular data. Simultaneously, their fossil record has also been increasingly studied and documented. Compression deposits from the Early Cretaceous of China and Eocene Baltic amber deposits of Europe, in particular, harbour an impressive diversity of Staphylininae rove beetles, whilst the subfamily is virtually unknown from the intervening time (Late Cretaceous through to Early Eocene). Compression and amber fossils present their own unique challenges for phylogenetic reconstruction. Early Cretaceous compression fossils are limited in the amount of phylogenetically informative data preserved, whilst Baltic amber fossils are ambiguous due to the previously estimated broad age ranges of the deposit and the repeated re-deposition of the amber. With the amount of available morphological and molecular data and broad temporally distributed fossil record we sought to explore: 1) the feasibility and impact of including fossils in the total-evidence phylogeny of Staphylininae and 2) the possibility of obtaining reasonable and refined age estimates for staphylinines preserved in Baltic amber; ergo, we attempt to answer the question: how old is Baltic amber?



## INFLUENCE OF COLONIAL MICROALGAE ON STRUCTURAL COMPLEXITY OF BIOFILMS AND VERTEBRATE TRACK FORMATION

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### Keywords

MISS, river, biofilms, pennate diatoms, colonial microalgae

Microbially induced sedimentary structures (MISS) have been related to the formation and preservation of both fossil and current vertebrate footprints. The relationship between the microalgal composition of modern biofilms and the formation of vertebrate tracks on the banks of the Negro River, Argentina, was analyzed. Predominance of filamentous and/or colonial microalgae (*e.g.*, *Lyngbya* sp., *Fragilaria construens*, *Melosira varians*, *Spirogyra* sp., *Anabaena* sp.) was registered in the layer of complex biofilms observed in two sites on the margin of the river, in July 2022. These species offer a network on which other microorganisms can develop or adhere (*e.g.*, epiphytic species), which give thickness to the layer. This complexity stabilizes the substrate and confers a plastic surface on which vertebrates step and leave a visible track. An increased flow of the river occurred in November 2022 and the associated sediment deposition, originated a new sediment layer on which pennate diatoms (*e.g.*, *Cymbella* sp., *Surirella* sp., *Ulnaria* sp., *Epithemia* sp., *Cocconeis* sp.) predominate in the initial stages of biofilm formation. This type of biofilm is less efficient in stabilizing the substrate, with respect to thicker MISS as microbial mats. However, biofilms with a predominance of high-profile microalgae, including erect, filamentous, chain-forming, with the ability to form long and spreading colonies, could confer a structural complexity to the biofilms that enhances footprint formation. Because the interweaving mesh of filamentous algae entangles sand grains more efficiently than a diatom biofilm and increases the cohesiveness of sediment.





## RESOLVING THE PHYLOGENETIC AFFINITIES OF THE ENIGMATIC THYLACOCEPHALA: SYNCHROTRON X-RAY TOMOGRAPHY SHEDS LIGHT ON THE TAGMATISATION OF THYLACOCEPHALANS

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### Keywords

X-ray tomography, synchrotron, appendages, La Voulte, Lagerstätte

Known from at least the Silurian to the Late Cretaceous, Thylacocephala is an enigmatic group of extinct euarthropods characterized by a folded shield, hypertrophied compound eyes, three pairs of raptorial appendages, eight pairs of gills and an eight to 22-segmented posterior trunk. Many questions remain concerning their phylogenetic affinities. They have been tentatively placed within various pancrustacean groups such as thecostracans, malacostracans or remipeds. These uncertainties on their phylogenetic relationships is mostly due to a lack of knowledge on their tagmatism, especially on the number, nature and morphology of their cephalic, raptorial and posterior trunk appendages. Conventional micro-computed X-ray tomography ( $\mu$ CT) has proven to be efficient in order to reconstruct the internal anatomy of thylacocephalans. However, it did not provide insight into their various kinds of appendages. Thus, we decided to apply Synchrotron X-ray Phase Contrast  $\mu$ CT to *Dollocaris ingens* Van Straelen, 1923 from the La Voulte-sûr-Rhône Lagerstätte, Ardèche, France (Callovian, Middle Jurassic). The presence of cephalic appendages, including mandibles, an anterior trunk, including the three raptorial appendages, and a posterior trunk have been demonstrated. Other important anatomical features were also characterized, such as the univalve nature of the carapace. The anatomical work produced new characters which could be used to test their phylogenetic affinities. The phylogenetic analyses confirm the monophyly of thylacocephalans and suggest that thylacocephalans form a pancrustacean monophyletic group, probably related to malacostracans.





## MORPHOBANK: A PALEONTOLOGICAL RESEARCH TOOL AND REPOSITORY FOR MORPHOLOGICAL MATRICES AND MEDIA

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### Keywords

Morphological Matrix, Systematics, Phylogenetics, Database, Repository



Most phylogenetic and systematics studies borrow from and build on the work of their predecessors, however, the lack of accessibility and reusability of morphological character matrices is a limiting problem in paleontology. MorphoBank offers solutions to these fundamental, reoccurring problems by providing an online morphological matrix editing tool, a repository for browsing and downloading morphological matrices, and analyses for tree building. MorphoBank allows users to upload or develop morphological character matrices by managing taxonomic names, characters, and character states. Users can even upload 2D and 3D images or import images from Integrated Digitized Biocollections (iDigBio) that can be annotated to illustrate a character state. Taxa that are scored for the character matrix can be marked extinct, and higher level taxonomy can be validated using NCBI Taxonomy and the Paleobiology Database (PBDB). MorphoBank currently uses the CIPRES Science Gateway for tree building using PAUP\* and is working on the integration of additional tree building algorithms (maximum likelihood and Bayesian) in CIPRES and an additional parsimony analysis option using Tree Analysis using New Technology (TNT). MorphoBank is also collaborating with PBDB for the transfer of over 600 data matrices describing phylogenetic research on fossils. As part of a partnership with the Journal of Vertebrate Paleontology (JVP), MorphoBank serves as a repository where authors upload matrices and related files. Video tutorials and educational content regarding best practices for morphological characters and matrix management are currently in development and are regularly added to the MorphoBank YouTube channel.



## SOWING THE SEEDS FOR IDENTIFYING PALEOENVIRONMENTAL CONTEXTS THROUGH ROOTS MORPHOLOGY

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### Keywords

Taphonomy, Paleobiology, Root Marks, Experimentation



Root traces are directly linked to the vegetation cover and plants are closely related to the environment. Despite root etching have been recorded in different archaeological and palaeontological contexts, studies going deeper into their morphological characterization in relation to different plant types are needed. Here we present an experimental study with the purpose of increasing the information that can be extracted from root marks in fossil sites for further palaeoecological interpretations. Deer ribs buried in contact with [1] subterranean roots, [2] subaerial roots, and [3] aquatic roots were exposed for 1 and 10 years. We characterized the different root morphologies and their depth recorded on bone surfaces by scanning electron microscopy (SEM) and high-resolution 3D optic microscope. Subterranean grass roots recorded the shape of these roots as arborescent and sinuous marks covering the entire rib surface. Subaerial roots from Bermuda grasses were concentrated at one end of the rib showing a reticulated and shallow etching. Aquatic common cattails roots left distinct fine deep and highly linear etching. These results indicate a clear differentiation between subterranean, subaerial and aquatic roots, allowing the distinction between terrestrial and aquatic environments to identify potential mixtures and transport (i.e., reworking) taphonomic processes. These are preliminary results of an ongoing investigation to characterize a greater number of plants, including shrubs and trees. Apart from bone surfaces, histological sections will be considered to characterize the microbial (bacterial or fungal) symbiotic association with these plants, which also leave distinct modifications.



## MIXING ACTIVE LEARNING AND NEW TECHNOLOGIES IN THE PALAEOLOGICAL CLASSROOM

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### Keywords

Palaeobiology, Digital Resources, 3D Technologies, Learning Objects, Teaching



The global COVID-19 crisis posed significant changes in the organization of curricular activities, limiting in-person practical classes and forcing the evaluation of new forms of teaching. Hybrid classes allowing in-person and remote students at the same time require the development of new pedagogical tools aimed at improving the individual and continuous assessment of students. Palaeontology classes heavily rely on face-to-face pedagogical experiences as well as the use of teaching materials like fossil specimens and replicas. This contribution presents several experiences developed for the Paleontology course of the Universidad de la República, Uruguay. New pedagogies that associate deep learning and general access were adapted to digital resources in three conceptual axes: active learning and meta-learning, continuous assessment, and learning objects. The mixing of active and collaborative learning experiences and 3D technologies in virtual context aimed to promote students' participation and engagement in the learning process in a hybrid setting. In particular, pedagogical materials aimed at encouraging and improving the use of R and online databases such as [pbdb.org](http://pbdb.org) were developed through online, collaborative, and interactive exercises to analyze and understand the large phenomena that occurred in the fossil record. Moreover, 3D digitization of specimens and paleontological sites were generated and interactive visualization platforms were used for the evaluation of morphological, stratigraphical, and taphonomical information. Finally, the project contemplates the development of multiplatform and multimedia learning objects based on the generated materials and intended to reach a wider audience.



## CALCULATING THE BRACHIOPOD SHELL SPIRAL USING 3D MODELS

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### Keywords

3D scanning, Morphometrics, Ontogeny, Taxonomy, Terebratulida



Brachiopod shell morphology has been widely studied in the literature to establish the group taxonomy and the ontogenetic development of the shell. Conventionally, several techniques have been performed for this purpose, such as: serial sectioning using acetate peels, thin and ultra-thin sections, or polished slides, and measuring the morphological characters using caliper and/or digital measurements. Some techniques imply a partial or total destruction of the fossil; and the non-destructive techniques do not allow the measurement of all the shell parameters. Structured light 3D scanning (*i.e.*, IR or visible light) can solve these issues, because it is a powerful tool able to 3D digitize the surface characteristics of the shells with a micrometer spatial resolution (0.035-0.175 mm per vertex, in this study). Twenty biconvex shells have been scanned with the purpose to study the shell length and curvature. These taxa include different genera of the order Terebratulida from varied geological periods, including Recent. Moreover, the shell curvature has been compared with a theoretical spiral to identify changes into the shell growth based on its deviations. Longitudinal profiles of each valve were obtained from 3D models, varying the angle of digital sectioning to understand how morphometric varies along the 3D surface, the growth lines, and the shell morphology (*i.e.*, folds, sulci, costae). Shell curvature seems to be related to the genus, showing a great potential for taxonomic purposes, and the deviations of the shell spiral can be used to determine the ontogeny and age.



## 3D GEOMETRIC MORPHOMETRIC ANALYSIS USING FOSSIL OTOLITHS OF SCIAENIDAE (OSTEICHTHYES, ACTINOPTERYGII)

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### Keywords

Otolith Morphology, High-Density Geometric Morphometrics, Phylogeny and  
Evolution, Species Biodiversity



Recent research has focused on integrating evolutionary observations from fish fossils with developmental data from living fish to improve our understanding of vertebrate phylogeny and evolution. Various approaches have been developed to quantify the relationship between morphology and phylogeny. However, since the fossil otolith is a 3D object, there is still limited knowledge of how successfully these approaches can be used to infer phylogeny. Current approaches such as 2D geometric morphometrics also has its limitations. This study uses a three-dimensional (3D) geometric morphometric approach to determine phylogenetic signals and infer phylogenies for fish species using otolith shape. Sciaenidae (croakers) serves as the case study to demonstrate this work, given their abundance and diversity established on both modern and fossil otoliths. We will introduce a protocol to quantify otolith shape allowing us to create a detailed virtual representation and examine structures of the otolith without risking damage to the fossil. In this study, we will be using modern otoliths from 30 representative genus of Sciaenidae. Our preliminary results suggest that high-density geometric morphometrics (HDGMM) may be a valuable tool in shape characterization and phenotypic integration among modern otoliths that can be applied in fossil otoliths. This protocol is done by droppings points on the 3D model and quantifying homologous points to understand the degree of phylogenetic signal in otolith shape. HDGMM thus has potential application in accurately classifying and categorizing different species and identifying key traits based on their evolutionary history, in turn important in the context of adaptation to a changing environment.



## A REVIEW OF HINGE INVERSION OF BIVALVIA

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### Keywords

Hinge, Evolution, Teeth Transposition, Phylogeny



This study focuses on the evolution of Bivalvia, one of the molluscan groups. Due to the preservation of only the hard parts of mollusks, such as the shell and its structure, these characteristics are used to reconstruct the phylogeny of Bivalvia. Specific traits such as byssus gland, adductor, and retractor muscles scars, and hinge structure provide important information for understanding the mode of living and habitat preference of these animals. The hinge, in particular, is an important structure that helps valves to remain closed and protect the soft body, also can indicate the shell shape and its lifestyle. Additionally, identification up to the genus level can be based on hinge type because it is genetically fixed at higher levels. However, some species may exhibit hinge inversion (transposition), where the hinge structures of one valve appear in the opposite valve, while both valves function normally. This abnormality has been observed in bivalve species from different geological ages and may serve as a marker of “evolutionary pathways”. A comprehensive study of various fossil taxa and genome-based investigation are needed. This short review aims to raise awareness of this topic and improve existing data to facilitate a more thorough study of the phylogenetic relationships within the group.



## NEW INSIGHTS INTO THE SEA SPIDERS' FOSSIL RECORD (ARTHROPODA: PYCNOGONIDA)

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### Keywords

Pycnogonida, Jurassic, Devonian, reflectance transformation imaging, microtomography



Sea spiders (Pycnogonida) are a poorly known yet fascinating group of benthic arthropods. Their position as an early offshoot within Chelicerata makes them a key-taxon to understand arthropods' early evolution. Yet, we still poorly understand pycnogonids' evolutionary history. Increasing efforts are made to reconstruct their phylogeny, but a comprehensive study of their fossil record is still missing. Sea spider fossils are rare, with only 13 species described, but they exhibit remarkable morphological disparity. The Palaeozoic fossils present a stunning diversity of forms, including swimming species, long segmented abdomen, etc. Contrastingly, the Mesozoic fossils are morphologically very similar to extant species. It was suggested that Jurassic and extant species all belong to the Order Pantopoda, but the status of many of the Palaeozoic fossils remains uncertain. We examined about 60 fossils of sea spiders disseminated in Museum collections in France and Germany, from the two most important Konservat-Lagerstätten for sea spiders, Hunsrück Slate (Western Germany – Devonian, c. a. 400 million years old) and La Voulte-sur-Rhône (Southern France – Jurassic, c. a. 160 million years old). Using Reflectance Transformation Imaging (RTI) and X-ray microtomography, we add evidence for previously undetected morphological features. We support the position of Jurassic pycnogonids within Pantopoda and shed light on their affinities with extant families. Based notably on the structure of the legs and of the terminal segments, we propose a new classification of Pycnogonida total-group. We finally show how these new data refine the use of sea spiders' fossil record as calibration points for future tree-dating analyses.



## DESIGNING AND 3D-PRINTING AN EXPERIMENTAL, CHEAP PHOTOGRAMMETRY ACCESSORY TO HELP MAKE STANDARDIZED PHOTOS FOR FOSSIL DIGITIZATION

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### Keywords

Paleoart, 3D print, paleontological models



3D-scanners are a fast and efficient fossil digitization process. However, they are usually expensive, and hard to use. Photogrammetry is a more affordable technique, and can be done with all kinds of cameras, even those available in mobile phones. However, it also requires a good understanding of specific techniques to carry out the whole process: from taking the correct images, to their digital integration and, finally, to obtain a complete 3D model. Here we propose a 3D- printable design of a photogrammetry device, that would let to take structured, well-optimized photos, with known distances and angles of the target fossil. The device consists of a 12-centimeter diameter base, to which is joined to an arm of variable length and height. At its ending, it has a bracket to which both standard cameras and cell phones can be attached. The model has been printed in PLA, a cheap and very common 3D print material. It also requires some basic pieces available at any hardware store, such as nuts and bolts. There are other existing models with the same purpose, but our device tries to combine efficiency, ease of use, ease of transport and low cost. Although this is a first prototype, it is desirable to test it -even on the field- and improve it, further spreading and facilitating the use and advantages of photogrammetry in Paleontology.



## ANALYZING DINOSAUR BOOKS FOR CHILDREN

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### Keywords

Dinosaur, Library, Media, Misconception



Paleontology, more specifically dinosaurs, is a topic with great media appeal, especially for children. In this sense, numerous printed materials are produced to meet this interest and marketed as books, games, and other materials for a younger audience. Given this scenario, this work proposed to analyze nine books about dinosaurs that contain information about these prehistoric beings. In this research, we divided the material into three categories: interactive, curiosity, and literature. To evaluate the information contained in the products, a textual analysis of all volumes was carried out to verify the reliability of the information. The wrong data were classified as either incomplete, incorrect, or inducing error. After this step, the information was listed and corrected based on the scientific literature. Among all the volumes, 321 pages were reviewed containing 41 instances of misconceptions: 31 incorrect and 10 inducing error. Among all the subjects studied, it was noted that the literature books — or those containing stories about dinosaurs — have the highest quality standard, with only one misconception among the three volumes analyzed, while the curiosity books had the highest number of errors, ignoring recent paleontology literature and having absurd facts about dinosaurs and other prehistoric beings. It is understood that the target audience of these products is children and that the information should be communicated in a more friendly way; however, no misconceptions should be tolerated in any material, especially those that reach an audience that is developing scientific reasoning skills. After this analysis, we volunteered to contact the publishers responsible for the materials and suggest the necessary corrections to prevent future misunderstandings from happening again.



## FUNCTIONAL PROPERTIES INDICATED BY SHAPE VARIATION IN NEUROCRANIAL MORPHOLOGY OF LAMNIFORM SHARKS (ELASMOBRANCHII: LAMNIFORMES)

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### Keywords

Ecology, Evolution, Functional Morphology, Skull Shape, Sensory Systems



Lamniform sharks (Elasmobranchii: Lamniformes) display diverse habitat and diet preferences. Based on museum specimens and published illustrations, we examined the variation of neurocranial (skull) shapes across all extant lamniform sharks. We ran landmark-based geometric morphometric analyses to infer the importance and patterns of sensory organs to habitats and diets in lamniform sharks, where variation in skull shape influenced by the rostral, olfactory, optic, and otic regions serves as a proxy of the relative importance of each sensory region (electroreception, olfaction, vision, and 'coordination') to its habitat and diet. Our study suggests that there are three basic skull shapes in lamniform sharks, an 'elongated-rostral' and 'reduced-optic' shape (Group 1; *Mitsukurina owstoni*), an 'intermediated-rostral-optic' shape (Group 2; *Carcharodon carcharias*, *Carcharias taurus*, *Cetorhinus maximus*, *Isurus oxyrinchus*, *I. paucus*, *Lamna ditropis*, *L. nasus*, *Megachasma pelagios*, *Odontaspis ferox*, and *O. noronhai*), and a 'shortened-rostral' and 'enlarged-optic' shape (Group 3; *Alopias pelagicus*, *A. superciliosus*, *A. vulpinus*, and *Pseudocarcharias kamoharai*), where all lamniform sharks have essentially one basic olfactory and otic region shape. Besides phylogenetic influences, we found that habitat and diet preferences in lamniform sharks are also broadly correlated with skull shapes where Group 1 is a sluggish species that feeds on midwater teleosts, cephalopods, and crustaceans, Group 2 sharks are largely represented by migratory species that feed on epipelagic food sources (e.g., zooplankton, teleosts, marine mammals), and Group 3 sharks are active species that feed on smaller teleosts and crustaceans. Our study provides new insights into the evolutionary history of lamniform sharks.



## WHO KILLED “DINO”? AN INDAGATIVE ACTIVITY FOR INTELLECTUALLY GIFTED SCHOOL STUDENTS

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### Keywords

Gamification, Geology Teaching, Inquiry-Based Learning, Paleontology,  
Role Playing



Inquiry-based learning is a suitable methodology for any educational stage. A particularly interesting group to work with using this methodology is that of students with high intellectual abilities. This work proposes an activity that includes methodological aspects of role playing, gamification, inquiry, etc. In addition, it allows working across a series of skills and attitudes such as creativity, cooperative work and problem solving. The common thread of the proposal is the arrival of an E-mail to the teacher in which he is asked for help to solve the mysterious death of Dino, a dinosaur whose time and specific location in which he lived are unknown. In this case, the students will have different roles as paleontologists, forensic technicians, etc. and they must solve the case through a sequence of clues. These are obtained by solving a series of situations related to geology and paleontology. They will be able to travel, in a reasoned way, to different geological periods to collect data (palaeogeography, climates and environments, etc.) and solve the different problems that are provided (maps, types of rocks, types of adaptations to the environment of Dino, etc.) at the same time that they must answer the main question: who killed Dino? These problems and the end result will not have a unique solution. The didactic objective is to evaluate in a different manner the instruments and methods that students use in solving problems, as well as their attitudes during the activity, using for this formative evaluation, summative evaluation or self-evaluation.



Underwater Chase in the Western  
Interior Seaway (*Tylosaurus*, *Archelon*,  
*Hesperornis*)  
Nickolaus Peter  
Palaeoart Competition (2<sup>nd</sup> Prize, tie)



# Virtual Field Trips





## VISIT TO THE PALAEOLOGICAL MUSEUM OF ELCHE

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### Keywords

Elche, Heritage, Management, Museum, Palaeontology



The Palaeontological Museum of Elche (MUPE) is located in the city of the same name, Elche, in the district of Baix Vinalopó, Alicante, Spain. In 1982, three years before of the Spanish Law 16/1985, on Spanish Historical Heritage, a group of palaeontology enthusiasts, with common motivations and interests, decided to create the Palaeontological Cultural Group of Elche (GCPE). The GCPE was a meeting point for palaeontology enthusiast in Elche and surroundings. Over time, new members added to the group and contacts were established with different Spanish universities and museums around the world. The Journal of Palaeontology and Mineralogy Cidarís, of which 32 issues have been edited, also begins to run. The palaeontological heritage of Elche was beginning to be known. In 1996, the collection was declared as a Museographic Collection of Palaeontology and incorporated into the Network of Museums of the Valencian Community. The growing interest of society makes that the City Council of Elche develop the Palaeontological Museum of Elche (MUPE), which opens on December 2004. Currently the museum is managed by the Cidarís Foundation and has incorporated geologists and biologists who work by projects. Since 2007, the museum has become a reference in Alicante as it is the only palaeontology museum in the entire province that develops research projects related to heritage and conservation, promoting as well didactic projects related to geological and paleontological heritage. This is the aim of FOPALI, the main work strategy implemented systematically with the professional help of GeaLand Patrimonio S.L.



## CALDERA – LIVING WITH THE SUPERVOLCANO (A SPECIAL EXHIBITION AT THE MUSEUM OF NATURE SOUTH TYROL)

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### Keywords

early Permian, megacaldera, terrestrial ecosystems, climate change, environmental change



Volcanoes are manifestations of the internal forces of the Earth and, as such, they profoundly fascinate us. Special attention has ever been directed towards mega-calderas and supervolcanoes because of their potentially devastating global impacts on life and climate; some of the most famous prehistoric supervolcanoes are linked to mass extinctions. This makes the Permian (ca. 280-million-year-old) supervolcano of Bolzano (NE Italy) especially interesting. The explosive super-eruptions that created the Athesian Volcanic Group extended over a time span of 12 million years. The volcanic rocks are intercalated with sedimentary successions deposited during periods of volcanic quiescence. These fluviolacustrine sediments, crop out in numerous small basins and are particularly interesting since they yield a wide variety of fossils, including vertebrate and invertebrate trace fossils, plants, and the oldest vertebrate of the Alps. The special exhibition at the Museum of Nature South Tyrol (17.03.2023-04.02.2024) provides important insights into the evolution of the supervolcano showing the visitor the different types of eruptions of the volcanic complex through time with the help of a 3D projection. The central part of the exhibition deals with the reconstruction of the Cisuralian terrestrial ecosystems at the tropics. Paleoenvironmental reconstructions by Davide Bonadonna, fossils, living plants and 3D reconstructed animals help the visitor to enter into a different time and space, some 280 million years ago, when the sediments were deposited in a megacaldera system laying at the tropics. And the rocks that were formed then are today used worldwide for exterior design and still influence the life of the locals, including the composition of the soils, the local climate and the historical and modern buildings.



## A QUICK VIRTUAL TOUR TO PLIO-PLEISTOCENE SEDIMENTARY UNITS IN BULACAN AND PANGASINAN, PHILIPPINES

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### Keywords

Paleobiodiversity, evolution, hot spot, Tartaro Formation, Anda



Philippines, in Southeast Asia, is one of most diverse marine wildlife in the world. To better understand the origin and evolution of tropical-subtropical biodiversity hotspots, there is a need to describe the hidden paleobiodiversity in areas like the Philippines. This virtual tour describes the Tartaro Formation, located at Bulacan, and three outcrops in the Municipality of Anda, Pangasinan. The Tartaro Formation, along the Madlum River, is located within the late Early Pliocene (3.6 to 3.75 Ma) in age. The exposures in the type locality show a sequence of thickly bedded sedimentary units which are poorly consolidated and distinctively greenish-gray. It also contains fossiliferous mudstone-sandstone beds and conglomeratic sandstones with coral rubble. Mollusks recorded from the Tartaro Formation include bivalves, cerithiids, conids, melongenids, muricids, and strombids. Notable findings in this formation are the new genus and species of the bivalve family Lucinidae, *Bulacanites obtusiplicatus* and the Lazarus taxon *Calyptrophorus* sp. On the other hand, the Municipality of Anda, Pangasinan is mapped within the Zambales Range Stratigraphic Group, which consists of ophiolitic rocks and their sedimentary carapace. The Late Miocene Santa Cruz Formation and the Pliocene-Middle Pleistocene Bolinao Limestone are mapped in the island. Fossil records include *Stegodon* sp., *Elephas* sp., holoplanktonic gastropods, and *Nautilus pompilius*. In this virtual tour, we visited outcrops in Barangay Awile and Pusong Island in Anda, Pangasinan. We hope that these efforts to identify and describe fossil records will contribute to understanding the past and how the Philippines plays a role in shaping this hotspot's evolution history.



*Jaekelopterus* cazando *Phacops*  
Navarro Guerrero  
Palaeoart Competition (Special Mention)





4th Palaeontological  
Virtual Congress